(serial)

NASA

National Aeronautics and
Space Administration

Budget Estimates

FISCAL YEAR 1991

Volume I

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GENERAL STATEMENT

The National Aeronautics and Space Administration conducts space and aeronautical research, development and flight activities for peaceful purposes designed to maintain United States preeminence in aeronautics and space. The President, in the National Space Policy, has charged NASA to conduct a balanced program of manned and unmanned exploration and to begin the systematic development of technologies necessary to enable and support a range of future manned missions. These activities will support the long-range goal of expanding human presence and activity beyond Earth orbit into the solar system. He declared a goal to establish the U.S. as the preeminent spacefaring nation and announced a national and international initiative to seek new solutions to environmental problems.

The NASA FY 1991 budget request of $15.1 billion supports the President's policy by providing the resources necessary for a vigorous national program ensuring leadership in areas critical to space as well as continued preeminence in aeronautics. This budget concentrates on:

- Initiation of a major program, Mission to Planet Earth, to provide long term data on changes in the global environment;

- Developing the technology base necessary to support a balanced program of robotic missions and human exploration beyond Earth orbit;

- Providing safe and effective assured access to space using both the Space Shuttle and Expendable Launch Vehicles;

- Moving forward into development hardware production and test for a permanently occupied Space Station in Earth orbit;

- Continuing an effective Space Science and Applications program to expand our knowledge of the Earth, its environment, the solar system and the universe, and human habitation of space;

- Providing the facilities, technology and expertise necessary for superiority in civil and military aviation;

- Providing opportunities for commercialization of space and for international cooperation in space.

The program elements outlined in this budget will provide a strengthened base for assuring and continuing the United States' role as leader in space and aeronautical research and development. Specific major areas of emphasis are:

Mission to Planet Earth

Funds are included to initiate the design and development of the Earth Observing System (EOS), as well as a secondary supporting initiative called Earth Probes. The EOS, which will use the polar orbiting platform, will include instruments to provide long-term, coordinated measurements of the key aspects of our global environment, a critical requirement for true understanding of the cause and extent of global change. The program is designed to utilize two series of three platforms as well as attached instruments on the Space Station Freedom. The EOS, which is the first major element of Mission to Planet Earth, will provide simultaneous, comprehensive Earth coverage and the measurement and data system capabilities necessary for long-term answers to global change. Earth Probes, an explorer-class program, is designed to address specific, highly focused Earth science investigations requiring unique orbits or special sensor environments, such as magnetically clean spacecraft for gravitational investigations. The program will provide an opportunity to take advantage of international cooperative efforts and technical innovations to address Earth science problems in a relatively short period of time as compared with major flight missions.

Human Exploration Initiative

The Human Exploration Initiative supports the President's major long-term goal of manned exploration beyond Earth's orbit. Included in this initiative is funding to augment a number of specific areas in order to: (1) increase the pace of exploration-related technology developments; (2) increase the science return from the Mars Observer mission; and (3) provide for initiation of development in 1992 of two Space Science missions, the Lunar Observer and Lifesat, which are necessary science precursors to eventual human exploration.

Space Transportation

The Space Shuttle has made a successful return to flight and the primary program focus is to conduct the planned flights in a safe and reliable manner and use the Shuttle's capability in the most efficient way. The budget provides for conducting up to nine flights in 1990, ten flights in 1991, and a build up in flight rate to twelve flights per year. Design and development activities will continue in FY 1991 on the Advanced Solid Rocket Motor, which will improve the safety, reliability and performance of the Shuttle fleet. Fabrication and procurement of a set of replacement structural spares continues as well as improvements to the Shuttle for extending the stay time in orbit.

The FY 1991 budget includes funding for an Advanced Propulsion Technology program. This program continues the joint NASA/DOD study efforts on the Advanced Launch System. Funding is also included for procurement of Upper Stages, for the continuation of Spacelab flights, the continued development of the Orbital Maneuvering Vehicle, and the Tethered Satellite System. Implementation of NASA's mixed fleet plan continues and funding is included to procure the necessary expendable launch vehicle services for selected Space Science and Applications missions.

Space Station

The Space Station Freedom is the critical element in this nation's exploitation of space in the 1990s. It will provide support and stability to scientific and technological investigations, further the commercial utilization of space, and provide experience in long term human operations in space, critical to future manned space exploration. It is an avenue of cooperation with our allies, demonstrating the peaceful uses of space for the benefit of all.

The Space Station's development continues to progress towards first element launch in early 1995. The program has undergone a major replanning effort to reduce near-term program funding requirements, consistent with the constrained funding environment, while maintaining the early 1995 launch schedule. Completion of the baseline station has been deferred but will still occur in the late 1990s. The rebaselined program is consistent with key commitments made to our international partners and the user community.

All major contractors are on board as well as many of the subcontractors. The funding proposed for FY 1991 will provide for increased requirements as the program moves through a critical transition into the development hardware fabrication and test phase following completion of the preliminary design reviews scheduled for late 1990.

Space Science and Applications

The FY 1991 budget provides for a carefully coordinated and logically phased set of research and development activities to:

- Advance our scientific knowledge of Earth and the global processes which shape our environment;
- Explore the solar system using automated spacecraft in conjunction with ground-based observations and research;
- Expand our comprehension of the universe beyond the solar system using the full range of capabilities from Explorer spacecraft to the Great Observatories;

- Increase our knowledge in the Life Sciences on key issues ranging from human performance and habitation in space to the basic life processes and the potential of life elsewhere in the universe;
- Understand and develop the potential benefits of the microgravity environment in materials sciences and other applications; and
- Maintain U.S. leadership in the world communications satellite market.

The Space Science and Applications program is taking full advantage of the Shuttle's return to flight. The Magellan and Galileo spacecraft were successfully launched in 1989. The Hubble Space Telescope, Gamma Ray Observatory, and Ulysses missions are scheduled for launch in 1990. Current planning supports the launch in 1991 of the Upper Atmospheric Research Satellite. The Cosmic Background Explorer was launched in 1989 on an expendable launch vehicle (ELV) and the Extreme Ultraviolet Explorer is scheduled for launch on an ELV in 1991. Development continues on TOPEX, the Scatterometer, the Global Geospace Science missions, the Mars Observer, the Advanced Communications Technology Satellite, the Advanced X-ray Astrophysics Facility and the Comet Rendezvous Asteroid Flyby (CRAF)/Cassini. Development and integration activities continue in preparation for future Spacelab flights and secondary payloads to conduct microgravity and life sciences experiments.

Commercial Activities

The FY 1991 budget confirms NASA's commitment to encouraging a healthy and expansive commercial space industry. Funding is included to provide expanded opportunities for access to space for Centers for Commercial Development of Space (CCDS) payloads through sounding rockets, small orbital ELV and the lease of a Shuttle middeck locker-type commercial payload module. There are a number of ways in which the private sector is being involved in developing the infrastructure for research and working in space. NASA continues to procure launch services from the private sector for a number of scientific satellite missions. Commercially-developed upper stages are being used where appropriate for planned missions. The Extended Duration pallet, to extend the Shuttle on-orbit stay time to 16 days, will be procured on a commercial basis.

Space Research and Technology

This program develops the technology base on which our current and future capabilities in space depend. The Civil Space Technology Initiative started in FY 1988, and the Exploration Technology program (formerly Pathfinder) started in FY 1989, are developing the advanced technology required for future missions. They will significantly enhance current capabilities in propulsion, power and related systems to access and operate in space.

Aeronautics Research and Technology

The goal of the Aeronautics program is to provide a technology base for the continued U.S. preeminence in the field of aeronautics. This is accomplished by maintaining a broad-based research and technology program utilizing advanced facilities, laboratories, computers and technical staff, with extensive involvement of the U.S. university and industrial sectors. The FY 1991 Research and Technology program is committed to developing the technology to improve our nation's competitiveness and in the international marketplace, with special focus on the High Speed regime, enhancing the safety of aviation, and increasing U.S. leadership in aviation for national security purposes.

Transatmospheric Research and Technology

The NASA efforts in this joint program with DOD are aimed at accelerating the development of critical technologies intended to enable a potential new class of vehicles in the future capable of flight to orbit or hypersonic cruise. Work will continue in the development of technology for hypersonic and transatmospheric vehicles for the National Aerospace Plane program with emphasis on lightweight thermal structures and subsonic, supersonic and hypersonic propulsion. Potential future applications include vehicles to transport people to orbit, hypersonic transport between points on Earth and national security.

Space and Ground Network, Communications and Data Systems

The FY 1991 budget provides vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. Work will continue on the replacement Tracking and Data Relay Satellite (TDRS) spacecraft and on the second TDRSS Ground Terminal, both of which are vitally needed to insure continuity of tracking support.

Academic Programs

This program will substantially expand graduate and undergraduate student fellowships, faculty fellowships, the historically black colleges and university research program, other minority universities, and the Space Grant College and Fellowship program. In FY 1991, funding for the Aerospace Education Services Program and the Innovative Student/Teacher Involvement program has been transferred from Research and Program Management to Research and Development in an effort to consolidate NASA's educational programs.

Institutional Capability

The NASA institutional capability is the underpinning for the successful accomplishment of the nation's aeronautics and space programs. Continued rebuilding of the in-house capabilities is necessary in order to support the ongoing programs and exciting new programs of the future. The FY 1991 budget provides funding for an increase in civil servants who are urgently needed to meet the increased workload associated with the Earth Observing System program, the Space Station Freedom program, and to enhance the capability of the workforce. To maintain the valuable NASA facilities, funding is included in the FY 1991 budget to continue the multi-year effort to restore, modernize, and maintain the aeronautical research and development facilities. To enable NASA to meet the challenges of the 1990's and beyond, funding is also included in the FY 1991 budget to allow NASA to begin to address the increasingly serious routine maintenance problems aging facilities experience.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FY 1991 BUDGET SUMMARY
(Million of Dollars)

	Budget Plan 1989	1990	1991
RESEARCH AND DEVELOPMENT	4,237.6	5,246.0	7,074.0
Space station	900.0	1,749.6	2,451.0
Space transportation capability development	674.0	562.4	773.4
Space science and applications	1,824.2	2,003.9	2,481.6
Technology utilization	16.5	23.7	24.4
Commercial use of space	28.2	32.8	76.6
Aeronautical research and technology	398.2	449.7	512.0
Transatmospheric research and technology	69.4	59.0	119.0
Space research and technology	285.9	285.9	495.9
Exploration mission studies	(14.9)	(15.0)	37.0
Safety, reliability and quality assurance	22.4	22.6	33.0
Academic programs	(23.6)	37.0	50.1
Tracking and data advanced systems	18.8	19.4	20.0
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS	4,451.6	4,555.7	5,289.4
Shuttle production and operational capability	1,121.6	1,119.5	1,302.0
Space transportation operations	2,612.7	2,636.0	3,118.6
Shuttle unresolved reduction		-175.0	
Space and ground networks, communications and data systems	717.3	975.2	868.8
CONSTRUCTION OF FACILITIES	281.7	437.3	497.9
RESEARCH AND PROGRAM MANAGEMENT	1,926.4	2,049.2	2,252.9
INSPECTOR GENERAL	(7.9)	8.7	11.0
TOTAL BUDGET SUMMARY	10,897.3	12,296.9	15,125.2
OUTLAYS	11,051.5	12,025.6	14,136.7

Human Exploration Initiative
Special Analysis

This special analysis identifies those NASA programs in the FY 1991 Budget which support the long-term goal stated in the National Space Policy: "...expanding human presence and activity beyond Earth orbit into the solar system...." In addition to planned funding increases reflecting the FY 1991 runout of the FY 1990 program, specific augmentations amounting to an additional $188 million were approved in a number of specific areas, reflecting a Presidential decision to (1) increase the pace of exploration-related technology developments; (2) increase the science return from the Mars Observer mission; and (3) include provisions for initiating in FY 1992 the development of two Space Science missions, the Lunar Observer and Lifesat, which are necessary science precursors to eventual human exploration.

The following provides a summary of the activities and FY 1991 funding requests for the various program elements which support the Human Exploration Initiative:

1. Space Research and Technology

The Space R & T program, for which the overall 1991 R&D funding request is $495.9 million, includes approximately $315 million supporting the development of a wide array of technologies for future human exploration activities. The latter amount includes a specific Presidential decision to accelerate the pace of exploration technology developments by increasing the 1991 funding by $88 million. The increased funding for exploration is largely provided for in the funding requests for two focused programs: the civil space technology initiative (CSTI) and exploration technology programs. The focused programs develop technologies for specific future applications within the flight programs. Examples of technologies for human exploration missions include atmospheric aerobraking, advanced automation and robotics, the SP-100 space nuclear power source (an interagency program with the departments of Defense and Energy), space transfer vehicle propulsion, cryogenic fuel transfer and conservation, regenerative life support systems, radiation protection shieldings, high-rate optical frequency and Ka-band communications, and science multispectral sensors.

2. Space Science

Two major elements of the Space Science program support planned human exploration missions: the planetary missions to Mars and the moon, and space life sciences. The Mars Observer mission will extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, atmospheric structure and circulation, topography, figure, gravity and magnetic fields of Mars. The spacecraft is being modified to enable the relay of data acquired by the balloon stations of the USSR Mars 1994 mission. A specific funding augmentation to provide additional science data required for the design of future Mars missions has been included in Mission Operations. The additional funds will extend the basic mission duration and upgrade image processing capability to provide more detailed topographical data to determine potential landing sites for future Mars missions. The on-going Planetary Research and Analysis program includes provision for the design of future Mars missions, such as the Mars Network and Mars Rover Sample Return mission. The second specific augmentation included in FY 1991 provides for the Lunar Observer mission definition in 1991, with start of development in 1992. This mission will provide detailed data on the moon's topography, geology and climatology. The data will assist in determining potential landing sites of optimal scientific merit. This mission would be launched in 1996. The requested level of funding in FY 1991 for the two specific augmentations approved ($30 million) coupled with the on-going programs, amounts to approximately $104 million. An additional increment of $124 million provides for the 1991 procurement costs for the expendable Titan III launch vehicle and transfer orbit stage for the Mars Observer, funding for which is included in Space Transportation.

The space life sciences program will play a central role in the human exploration program. The fundamental objective is how to enable humans to operate effectively in space for long continuous periods of time. The space life sciences program has several research and hardware development programs designed to gather and analyze data to answer fundamental questions about the body's ability to adjust to working in space. Data gathered on Space Shuttle missions, complemented by data furnished by the Soviet Union, and experiments eventually on the Space Station will assist in determining exercise protocols, countermeasures, productivity, medical support requirements, and the need, if any, for artificial gravity on long-duration missions. Another issue, that of space radiation effects, will be addressed by the planned flight of a series of biosatellites in Earth polar orbits. In 1991, the definition studies for the Lifesats will be continued, leading to initiation of development in 1992. Within the total funding request of $163 million for space life sciences in 1991, approximately $80 million has been identified as pertaining to human exploration.

3. Space Transportation Capability Development

A key issue for conducting human exploration missions is how large amounts of cargo can be transported to Earth orbit in the most cost-effective manner possible. Timeliness, reliability, and cost are the key parameters. Preliminary studies indicate that a significant increase in the lift capability to low Earth orbit will be required. In the Advanced Launch System program, NASA and the Department of Defense are working together on the advanced cost-effective technologies required to meet both agencies future needs. In addition, NASA has studies underway in 1990 on the Shuttle-C, an umanned heavy lift vehicle derived from Shuttle components. In 1991, NASA will pursue under its Advanced Transportation Technology program definition activities of a heavy-lift launch vehicle to support Lunar and Mars missions as well as playing an increased role in funding the NASA/DOD development of the low-cost advanced main engine propulsion system critical to any advanced transportation system. In addition, systems analysis and concept definition of manned launch vehicles and transfer stages and of unmanned cargo vehicles will be conducted within Advanced Programs (advanced transportation). The 1991 funding level for these activities is planned at approximately $64 million. This includes a specific augmentation of $50 million. The total includes $44 million for the Advanced Launch System. Department of Defense funding for the ALS in 1991 is estimated at $85 million.

4. Exploration Mission Studies

Mission studies provide the necessary mission design options and integrated analyses of the tradeoffs between mission plans and alternative technology approaches. In addition, analyses of science opportunities are conducted. Mission integration studies encompass transportation systems, lunar and martian surface systems development and use of in situ resources, power and propulsion systems, life support requirements and robotics, contracted mission analyses and innovative concept studies. In 1990, various groups such as the NASA Advisory Council and the National Academy of Sciences will conduct independent reviews of exploration planning activities, including examination of proposed innovative concepts to reduce cost and risks. The 1991 funding level requested for these studies is $37 million.

5. Space Station Freedom

The Space Station Freedom will play a key role in human exploration, first as a research base and subsequently as a transportation node. As a research base, experiments in space life sciences and demonstrations of robotic technologies will provide vital information. As a transportation node, the Freedom will serve as the essential way-station for payloads and crew launched from or returning to Earth, as well as provide an on-orbit assembly capability. Within the total R&D budget request for Space Station for FY 1991 of $2,451 million, $20 million has been included to

assess and do preliminary designs of (1) a high-pressure space suit, serviceable on-orbit, needed to support frequent extravehicular activities for assembly operations; (2) solar dynamics power and a hybrid power distribution system to generate the additional power required for exploration-related activities; and, (3) an advanced propulsion system to provide reaction control and reboost capabilities in response to the orbit-keeping requirements induced by the exploration activities.

6. Transatmospheric Research and Technology

In addition to the launch vehicle propulsion and definition studies for heavy lift vehicles, NASA and the DOD are collaborating on the National Aerospace Plane (NASP). This next-generation advanced technology program is focused on the development of a revolutionary experimental single-stage-to-orbit flight vehicle with airbreathing primary propulsion and horizontal takeoff and landing. The program includes technology development efforts in materials and structures, propulsion, controls and computational fluid dynamics. A decision in the second quarter of FY 1993 will determine whether to proceed to the next phase of the program, which consists of designing, constructing and flight testing an experimental flight vehicle. The 1991 budget proposes $277 million in total ($119 million for NASA and $158 million for DOD) for the continued research and development of the NASP.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 1991 ESTIMATES
SUMMARY RECONCILIATION OF APPROPRIATIONS TO BUDGET PLANS

(Millions of Dollars)

	TOTAL	Research and Development	SFC&DC	C of F	R&PM	Inspector General
Fiscal Year 1989						
Appropriation P. L. 100-404	10,701.0	4,191.7	4,364.2	290.1	1,855.0	(7.9)
Transfers between accounts	0.0	-29.0	-12.6	-23.4	65.0	---
Transfers between Fed Agencies	196.5	74.9	100.0	15.0	6.6	---
Lapse of FY 89 Unobligated funds	-0.2	---	---	---	-0.2	---
Total Budget Plan	10,897.3	4,237.6	4,451.6	281.7	1,926.4	(7.9)
Fiscal Year 1990						
Appropriation P. L. 101-144	12,572.9	5,366.0	4,614.6	601.3	1,982.2	8.8
Reduction pursuant to P. L. 101-144	-195.8	-84.2	-71.5	-9.3	-30.7	-0.1
Reduction pursuant to P. L. 101-239	-155.2	-60.8	-62.4	-4.0	-28.0	---
Transfers between accounts	0.0	25.0	---	-92.0	67.0	---
Transfer for Pay Raise	0.0	---	---	-33.0	33.0	---
Required Transfer Authority	0.0	---	---	-25.7	25.7	---
Transfer from FY 1987 funds	75.0	---	75.0	---	---	---
Total Budget Plan	12,296.9	5,246.0	4,555.7	437.3	2,049.2	8.7
Fiscal Year 1991						
Appropriation Request/Budget Plan	15,125.2	7,074.0	5,289.4	497.9	2,252.9	11.0

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1991 ESTIMATES

SUMMARY OF BUDGET PLANS BY INSTALLATION BY APPROPRIATION

(Thousands of Dollars)

	Total			Space Flight Control and Data Communications			Research and Development			Construction of Facilities			Research and Program Management		
	1989	1990	1991	1989	1990	1991	1989	1990	1991	1989	1990	1991	1989	1990	1991
Johnson Space Center	1,935,283	2,505,052	2,979,066	1,049,250	1,101,100	1,134,600	581,678	1,021,703	1,445,751	24,925	61,245	58,560	299,435	321,004	340,155
Kennedy Space Center	1,229,514	1,341,241	1,546,403	824,200	836,100	954,200	112,020	152,668	227,361	24,571	71,247	62,595	268,723	281,226	302,247
Marshall Space Flight Center .	2,997,505	2,862,639	3,692,980	1,760,400	1,640,500	2,075,700	946,419	927,363	1,283,007	37,269	22,785	52,415	253,417	271,991	281,858
Stennis Space Center	82,174	74,138	87,296	21,300	24,600	24,400	16,303	12,568	15,646	21,045	11,555	18,910	23,526	25,415	28,340
Goddard Space Flight Center ..	1,458,704	1,851,693	2,229,782	548,259	593,899	701,502	641,839	958,164	1,188,485	14,104	29,330	35,135	254,502	270,300	304,600
Jet Propulsion Laboratory	712,666	719,841	897,325	124,669	140,611	162,500	583,621	567,260	700,765	4,376	11,970	34,060	0	0	0
Ames Research Center	511,989	563,357	630,405	16,700	17,000	21,900	288,416	311,478	361,124	29,098	43,400	33,890	177,775	191,479	213,491
Langley Research Center	474,003	497,782	555,123	14,300	9,100	9,700	241,296	263,089	296,283	29,217	25,550	31,970	189,190	200,043	217,170
Lewis Research Center	623,185	819,412	1,080,588	11,000	59,000	114,400	389,314	520,485	693,692	26,683	30,885	40,080	196,188	209,042	232,416
Headquarters	817,925	1,129,215	1,286,947	81,522	308,776	90,438	456,694	511,273	861,886	16,100	30,500	2,000	263,609	278,666	332,623
Undistributed Reduction	0	-175,000	0	0	-175,000	0	0	0	0	0	0	0	0	0	0
Undistributed Construction of Facilities:															
Various Locations	32,272	72,525	100,285	0	0	0	0	0	0	32,272	72,525	100,285	0	0	0
Facility Planning and Design	22,000	26,300	28,000	0	0	0	0	0	0	22,000	26,300	28,000	0	0	0
Total Budget Plan	10,897,225	12,288,195	15,114,200	4,451,600	4,555,686	5,289,400	4,237,600	5,246,051	7,074,000	281,660	437,292	497,900	1,926,365	2,049,166	2,252,900
Inspector General	(7,915)	8,659	11,000	---	---	---	---	---	---	---	---	---	---	---	---
Total Agency	10,897,225	12,296,854	15,125,200												

DISTRIBUTION OF FULL TIME EQUIVALENT WORKYEARS BY INSTALLATION

	1989 ACTUAL	1990 BUDGET ESTIMATE	1990 CURRENT ESTIMATE	1991 BUDGET ESTIMATE
JOHNSON SPACE CENTER	3,437	3,605	3,590	3,625
KENNEDY SPACE CENTER	2,316	2,357	2,433	2,549
MARSHALL SPACE FLIGHT CENTER	3,442	3,607	3,583	3,654
STENNIS SPACE CENTER	162	174	179	215
GODDARD SPACE FLIGHT CENTER	3,639	3,651	3,740	3,855
AMES RESEARCH CENTER	2,117	2,153	2,148	2,181
LANGLEY RESEARCH CENTER	2,838	2,888	2,887	2,932
LEWIS RESEARCH CENTER	2,662	2,743	2,725	2,809
HEADQUARTERS	1,562	1,779	1,703	1,865
(SPACE STATION PROJECT OFFICE - LEVEL II)	(184)	(348)	(218)	(264)
INSPECTOR GENERAL	127			
SUBTOTAL, FULL-TIME PERMAMENT WORKYEARS	22,302	22,957	22,988	23,685
OTHER THAN FULL-TIME PERMAMENT WORKYEARS	752	743	747	781
TOTAL, CEILING CONTROLLED FTE	23,054	23,700	23,735	24,466

NOTE: THE INSPECTOR GENERAL'S OFFICE HAS A SEPARATE APPROPRIATION STARTING FY 1990

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1991 MULTI-YEAR BUDGET ESTIMATES

As directed by the NASA FY 1989 Authorization Law (P.L. 100-685), the attached table contains the budget estimates for FY 1991, 1992, and 1993 to implement the President's FY 1991 program. The President's 1991 program funds the development starts of two new programs in 1992. In Life Sciences, funding is included for the Lifesat project. In Planetary Exploration, funding is included for the Lunar Observer project. Both of these missions are an integral part of the Human Exploration Initiative. In addition, an undistributed amount of funding is included for the Human Exploration Initiative beginning in FY 1992. The final allocation of this amount will take into account the recommendations of the National Space Council in the detailed planning for the President's Human Exploration Initiative and will be based on technical readiness and technological opportunities.

The funding estimates for FY 1992 and 1993 should not be construed as the final budget estimates. The annual NASA budget formulation process undertakes a through review of the technical progress, current funding requirements, Congressional action, and current priorities for ongoing research together with research opportunities which often cannot be forecast two or three years in advance. These intensive reviews are conducted each year prior to final recommendations being included in the annual budget requests.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1991 MULTI-YEAR BUDGET ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	1989 PAST YEAR	1990 CURRENT YEAR	1991 BUDGET YEAR	1992 ESTIMATE	1993 ESTIMATE
RESEARCH AND DEVELOPMENT	4238	5246	7074	8755	10176
SPACE STATION	900	1750	2451	2907	3031
SPACE TRANSPORTATION CAPABILITY DEVELOPMENT	674	562	773	916	910
PHYSICS & ASTRONOMY	737	861	985	1177	1197
LIFE SCIENCES	79	106	163	209	298
PLANETARY EXPLORATION	417	392	485	600	684
SPACE APPLICATIONS	591	645	848	1102	1965
SPACE SCIENCE AND APPLICATIONS	1824	2004	2482	3088	4143
TECHNOLOGY UTILIZATION	17	24	24	30	26
COMMERCIAL USE OF SPACE	28	33	77	120	140
COMMERCIAL PROGRAMS	45	57	101	151	166
AERONAUTICAL RESEARCH & TECHNOLOGY	398	450	512	555	575
TRANSATMOSPHERIC RESEARCH & TECHNOLOGY	69	59	119	72	68
SPACE RESEARCH & TECHNOLOGY	286	286	496	461	468
EXPLORATION MISSION STUDIES	(15)	(15)	37	45	45
HUMAN EXPLORATION INITIATIVE				444	649
SAFETY, RELIABILITY & QUALITY ASSURANCE	22	23	33	36	38
ACADEMIC PROGRAMS	(24)	37	50	59	60
TRACKING AND DATA ADVANCED SYSTEMS	19	19	20	22	23
SPACE FLIGHT, CONTROL & DATA COMMUNICATIONS	4452	4556	5289	5902	6117
SHUTTLE PRODUCTION & OPERATIONAL CAP	1122	1120	1302	1395	1372
SPACE TRANSPORTATION OPERATIONS	2613	2636	3119	3436	3560
UNRESOLVED SHUTTLE REDUCTION		-175			
SPACE & GROUND NETWORK, COMM AND DATA SYSTEMS	717	975	869	1071	1185
CONSTRUCTION OF FACILITIES	282	437	498	523	405
RESEARCH AND PROGRAM MANAGEMENT	1926	2049	2253	2444	2544
INSPECTOR GENERAL	(8)	9	11	14	14
TOTAL NASA	10897	12297	15125	17637	19257

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

GENERAL STATEMENT

The objectives of the National Aeronautics and Space Administration program of research and development are to extend our knowledge of the Earth, its space environment, and the universe; to expand the technology for practical applications of space technology; to develop and improve manned and unmanned space vehicles; and to assure continued development of the long-term aeronautics and space research and technology necessary to accomplish national goals. These objectives are achieved through the following elements:

SPACE STATION: A program to develop a United States space station to continue the Nation's leadership in space and to provide for enhancement of science and applications programs and to further the commercial utilization of space while stimulating advanced technologies.

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT: A program to provide for the development and use of capabilities related to the Space Shuttle. The principal areas of activity in Space Transportation Capability Development are efforts related to the development and flight certification of the jointly developed U.S./Italy Tethered Satellite System, development of the Orbital Maneuvering Vehicle, development and operations of the Spacelab systems, the development and procurement of upper stages that place satellites in high altitude orbits,the engineering and technical base support at NASA centers, payload operations and support equipment, advanced transportation technology development and study activities, and advanced programs study and evaluation efforts.

SPACE SCIENCE AND APPLICATIONS: A program using space systems, supported by ground-based and airborne observations: (1) to conduct a broad spectrum of scientific investigations to advance our knowledge of the Earth and its space environment, the Sun, the planets, interplanetary and interstellar space, the stars of our galaxy and the universe; and (2) to identify and develop the technology for the useful applications of space techniques in the areas of advanced communications satellite systems technology; materials processing research and experimentation; and remote sensing to acquire information which will assist in the solution of Earth resources and environmental problems.

TECHNOLOGY UTILIZATION: The program includes activities to accelerate the dissemination to both the public and the private sectors of advances achieved in NASA's research, technology, and development program.

COMMERCIAL USE OF SPACE: A program to increase private sector awareness of space opportunities and encourage increased industry investment and participation in high technology, space-based research and development.

AERONAUTICS AND SPACE TECHNOLOGY: A program to conduct the fundamental long-term research and to develop the discipline and systems technology required to maintain United States leadership in aeronautics and space.

SAFETY, RELIABILITY, AND QUALITY ASSURANCE: A program to enhance the safety and technical execution of NASA programs.

ACADEMIC PROGRAMS: This program includes activities to support agency-wide university, minority university programs, and elementary and secondary school programs.

TRACKING AND DATA ADVANCED SYSTEM: This program includes activities to perform studies and provide for the development of systems and techniques leading to improve tracking and data program capabilities.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
RESEARCH AND DEVELOPMENT
FISCAL YEAR 1991 ESTIMATES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Millions of Dollars)		
SPACE STATION	900.0	2050.2	1749.6	2451.0
SPACE TRANSPORTATION CAPABILITY DEVELOPMENT	674.0	639.0	562.4	773.4
SPACE SCIENCE AND APPLICATIONS	1824.2	1995.3	2003.9	2481.6
Physics and astronomy..................	737.4	894.5	861.4	985.0
Life sciences..........................	79.1	124.2	106.3	163.0
Planetary exploration..................	416.6	396.9	391.7	485.2
Earth sciences.........................	403.4	434.3	439.3	661.5
Materials processing...................	75.6	92.7	99.0	97.3
Communications.........................	92.2	18.6	78.0	52.8
Information systems....................	19.9	34.1	28.2	36.8
COMMERCIAL PROGRAMS	44.7	61.0	56.5	101.0
Technology utilization	16.5	22.7	23.7	24.4
Commercial use of space................	28.2	38.3	32.8	76.6
AERONAUTICS AND SPACE TECHNOLOGY	753.5	927.9	794.6	1163.9
Aeronautical research and technology...	398.2	462.8	449.7	512.0
Transatmospheric research and technology	69.4	127.0	59.0	119.0
Space research and technology..........	285.9	338.1	285.9	495.9
Exploration mission studies............	(14.9)	(20.0)	(15.0)	37.0
SAFETY, RELIABILITY AND QUALITY ASSURANCE	22.4	23.3	22.6	33.0
ACADEMIC PROGRAMS..........................	(23.6)	35.0	37.0	50.1
TRACKING AND DATA ADVANCED SYSTEMS.......	18.8	19.9	19.4	20.0
TOTAL	4237.6	5751.6	5246.0	7074.0

RESEARCH AND DEVELOPMENT

For necessary expenses, not otherwise provided for, including research, development, operations, services, minor construction, maintenance, repair, rehabilitation and modification of real and personal property; purchase, hire, maintenance, and operation of other than administrative aircraft, necessary for the conduct and support of aeronautical and space research and development activities of the National Aeronautics and Space Administration: [$5,366,050,000] *$7,074,000,000*, to remain available until September 30, [1991: *Provided*, That of the funds made available under this heading, $1,800,000,000 is for the Space Station Program only, $750,000,000 of which shall not become available for obligation until June 1, 1990, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided further*, That of the funds made available under this heading, $320,000,000 is for space transportation capability development only, which amount shall not become available for obligation until April 15, 1990, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided further*, That of $2,064,600,000 made available under this heading for space science and applications, only $1,000,000,000 shall be available prior to April 1, 1990, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided further*, That no funds appropriated by this Act or any other Act may be used to enter into contracts of the National Aeronautics and Space Administration for the comet rendezvous and asteriod flyby and Cassini missions (CRAF/Cassini) if the estimated total budget authority for development of the two spacecraft, through launch plus 30 days of the Cassini mission, exceeds $1,600,000,000] *1992, of which $2,451,000,000 is for the Space Station Freedom. Further, for the Space Station Freedom, $2,907,000,000 is to be available for obligation on October 1, 1991 and to remain available until September 30, 1993; and further, for the Space Station Freedom, $3,031,200,000 to be available for obligation on October 1, 1992 and to remain available until September 30, 1994: Provided, That for the Space Station Freedom rephased program, the funds appropriated for U.S. program development will not exceed $13 billion in fiscal year 1984 terms, adjusted for inflation and commercial participation. (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990; additional authorizing legislation to be proposed.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

REIMBURSABLE SUMMARY
(In thousands of dollars)

	Budget Plan		
	FY 1989	FY 1990	FY 1991
Space station	--	52	52
Space transportation capability development	101,101	222,672	212,936
Space science and applications	489,967	369,202	308,823
Commercial programs	2,660	6,975	6,500
Academic programs	200	200	200
Safety, reliability and quality assurance	1,476	---	---
Space research and technology	26,051	23,871	24,650
Aeronautical research and technology	75,191	62,191	54,263
Transatmospheric research and technology	2,881	3,190	2,338
Tracking and data advanced systems	---	500	---
Energy technolgy	22,719	20,038	16,945
Total	722,246	708,891	626,707

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1991 ESTIMATES
DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Goddard Space Flt Center	Jet Propulsion Lab	Ames Research Center	Langley Research Center	Lewis Research Center	NASA HQ
Space Station	1989	900,000	336,626	18,441	161,372	399	102,172	11,832	3,253	3,585	125,728	136,592
-------------	1990	1,749,623	775,395	47,650	311,004	250	184,945	9,055	1,303	1,800	251,215	167,006
	1991	2,451,000	1,051,065	87,000	531,247	260	140,459	9,200	2,000	3,020	369,446	257,303
Space Trans Cap Dev	1989	674,000	149,100	80,200	396,200	11,200	10,600	2,200	---	2,500	1,100	20,900
------------------	1990	562,381	158,900	86,500	287,781	5,600	5,900	300	---	600	400	16,400
	1991	773,400	243,100	117,200	312,000	6,100	9,800	500	---	1,400	6,500	76,800
Space Sci and Apps	1989	1,824,200	55,402	11,030	342,731	1,103	512,198	512,137	98,989	23,721	99,322	167,567
------------------	1990	2,003,848	69,593	14,430	264,227	1,085	745,599	504,203	110,064	23,895	91,575	179,177
	1991	2,481,600	95,376	16,644	317,798	1,195	1,015,479	607,018	122,187	27,170	70,438	208,295
Physics and Astronomy	1989	737,400	14,570	7,930	307,942	---	295,058	22,500	20,000	150	---	69,250
	1990	861,378	15,747	10,330	215,604	---	512,243	16,037	20,246	---	---	71,171
	1991	985,000	17,210	10,344	272,374	---	559,240	30,777	9,305	---	450	85,300
Life Sciences	1989	79,100	30,100	3,100	10	10	200	945	31,900	351	84	12,400
	1990	106,278	43,475	4,100	80	15	395	1,200	39,473	440	100	17,000
	1991	163,000	67,400	6,300	125	25	400	1,900	61,000	700	150	25,000
Planetary Exploration	1989	416,600	9,312	---	134	---	17,870	326,324	15,074	25	---	47,861
	1990	391,086	8,996	---	150	---	17,291	304,033	13,543	---	---	46,073
	1991	485,200	9,400	---	160	---	18,200	393,440	14,200	---	---	49,800
Earth Science & Apps	1989	403,400	25	---	8,021	998	182,403	134,261	30,315	19,920	---	27,457
	1990	439,299	---	---	8,562	1,070	196,430	147,420	32,640	21,450	---	31,727
	1991	661,500	---	---	8,730	1,170	412,650	148,500	32,850	23,500	---	34,100
Materials Proc in Space	1989	75,600	1,295	---	26,624	---	---	18,623	100	3,275	19,770	5,913
	1990	99,015	1,375	---	38,081	---	---	27,029	---	2,005	26,727	3,798
	1991	97,300	1,366	---	33,909	---	---	22,948	---	2,970	30,058	6,049
Communications	1989	92,200	100	---	---	---	3,792	5,029	---	---	79,468	3,811
	1990	77,975	---	---	---	---	3,170	4,184	---	---	64,748	5,873
	1991	52,800	---	---	---	---	3,497	4,603	---	---	39,780	4,920
Information Systems	1989	19,900	---	---	---	95	12,075	3,655	1,600	---	---	1,875
	1990	28,217	---	---	1,750	---	16,070	3,500	4,162	---	---	2,735
	1991	36,000	---	---	2,500	---	21,492	4,850	4,032	---	---	3,126

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1991 ESTIMATES
DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Goddard Space Flt Center	Jet Propulsion Lab	Ames Research Center	Langley Research Center	Lewis Research Center	NASA HQ
Commercial Programs	1989	44,700	3,736	1,232	1,540	3,481	1,074	1,035	1,114	799	721	29,968
	1990	56,532	1,665	1,260	1,240	4,690	1,440	1,050	740	640	440	43,367
	1991	101,000	4,210	3,500	1,970	7,110	2,415	1,000	1,225	690	704	78,080
Technology Utilization	1989	16,500	2,164	255	304	770	824	1,035	386	799	469	9,494
	1990	23,700	415	510	340	940	940	1,050	340	640	440	18,085
	1991	24,400	510	600	260	1,110	1,365	1,000	475	690	704	17,670
Commercial Use Of Space	1989	28,200	1,572	977	1,236	2,711	250	---	728	---	252	20,474
	1990	32,832	1,250	750	900	3,750	500	---	400	---	---	25,282
	1991	76,600	3,700	2,900	1,710	6,000	1,050	---	750	---	---	60,410
Aero & Space Technology	1989	753,500	15,280	600	43,904	---	8,780	40,531	184,900	207,056	161,033	91,328
	1990	794,654	13,050	1,427	60,565	---	11,490	35,445	197,995	230,107	174,785	69,782
	1991	1,163,900	48,100	1,400	116,300	---	10,400	64,500	234,200	257,300	241,000	189,900
Aero Research & Tech	1989	398,200	---	---	1,800	---	200	300	151,500	141,500	94,100	8,800
	1990	449,756	---	---	2,100	---	600	800	165,100	159,900	111,000	16,256
	1991	512,000	---	---	2,000	---	600	900	187,000	163,000	125,000	12,700
Space Research & Tech	1989	285,900	15,280	600	42,104	---	8,580	40,231	28,850	55,063	60,873	34,231
	1990	285,871	13,050	1,427	58,465	---	10,890	34,645	27,895	48,607	54,385	30,499
	1991	495,900	20,100	1,400	110,300	---	9,800	63,600	43,400	87,300	111,000	68,200
Exploration Mission Studies	1989	0	---	---	---	---	---	---	---	---	---	---
	1990	0	---	---	---	---	---	---	---	---	---	---
	1991	37,000	28,000	---	4,000	---	---	---	---	---	---	5,000
Transatmos Res & Tech	1989	69,400	---	---	---	---	---	---	4,550	10,493	6,000	48,297
	1990	59,027	---	---	---	---	---	---	5,000	21,600	9,400	23,027
	1991	119,000	---	---	---	---	---	---	3,000	7,000	5,000	104,000

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1991 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Goddard Space Flt Center	Jet Propulsion Lab	Ames Research Center	Langley Research Center	Lewis Research Center	NASA HQ
Tracking & Data Acqui	1989	18,000	---	---	---	---	5,700	12,065	---	---	---	235
	1990	19,345	---	---	---	---	5,600	13,400	---	---	---	345
	1991	20,000	---	---	---	---	5,700	13,960	---	---	---	340
Academic Programs	1989	0	---	---	---	---	---	---	---	---	---	---
	1990	37,038	1,700	901	1,546	793	1,782	907	1,276	3,947	1,070	23,116
	1991	50,100	1,750	937	1,592	831	1,832	937	1,312	3,895	1,104	35,910
Safety,Reliability & QA	1989	22,400	1,534	437	672	120	1,315	3,021	152	3,635	1,410	10,104
	1990	22,630	1,400	500	1,000	150	1,400	2,900	100	2,100	1,000	12,080
	1991	33,000	2,150	600	2,100	150	2,400	3,650	200	2,800	3,700	15,250
TOTAL BUDGET PLAN	1989	4,237,600	561,670	112,020	946,419	16,303	641,039	583,621	200,416	241,296	309,314	456,694
	1990	5,246,051	1,021,703	152,660	927,363	12,568	958,164	567,260	311,470	263,009	520,405	511,273
	1991	7,074,000	1,445,751	227,361	1,203,007	15,646	1,188,405	700,765	361,124	296,283	693,092	861,886

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT

SPACE STATION FREEDOM

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Development	842,000	1,970,200	1,661,223	2,299,800	RD 1-6
Flight telerobotic servicer	46,000	15,000	79,400	106,300	RD 1-22
Operations	--	25,000	--	8,900	RD 1-24
Advanced programs	12,000	25,000	9,000	36,000	RD 1-25
Orbital debris radar	--	15,000	--	--	RD 1-28
Total	900,000	2,050,200	1,749,623	2,451,000	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	336,626	885,874	775,505	1,051,065
Kennedy Space Center	18,441	77,379	47,650	87,027
Marshall Space Flight Center	161,372	382,299	311,004	531,238
Stennis Space Center	399	100	250	260
Goddard Space Flight Center	102,172	155,423	185,045	140,529
Jet Propulsion Laboratory	11,832	25,324	9,055	9,200
Ames Research Center	3,253	5,774	1,303	2,000
Langley Research Center	3,585	3,778	1,800	3,020
Lewis Research Center	125,728	301,049	251,105	369,484
Headquarters	136,592	213,200	166,906	257,177
Total	900,000	2,050,200	1,749,623	2,451,000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT | SPACE STATION FREEDOM

OBJECTIVES AND JUSTIFICATION

Development of the United States (U.S.) permanently manned Space Station, as directed by President Reagan in 1984, and reaffirmed by President Bush in 1989, will add new momentum to the civil space program and is essential to preserving U.S. preeminence in spaced based science, technology and manned space flight. The Space Station will uniquely enhance the U.S. space science programs, further the commercial utilization of space, and stimulate the development and application of advanced technologies of national importance. The Space Station Freedom (SSF) program gives NASA our first opportunity to gain direct experience in very long term human operations in space, and knowledge essential to future space exploration. It will serve as a test bed for the development of technologies for continuing human exploration of the moon and the planets, and as a way station and transportation hub for the implementation of this exploration. It is also the centerpiece of cooperation with our international partners demonstrating the peaceful use of space for the benefit of all.

The SSF will be unique because it will provide the United States with a permanently manned presence in space and it is designed to accommodate diverse capabilities. This diversity is reflected in the Space Station's design, which features pressurized laboratories and accommodations for attached payloads. This new national laboratory, a research center in space, will stimulate new technologies, enhance industrial competitiveness, further commercial space enterprises, and add greatly to the storehouse of scientific knowledge. Perhaps the most significant feature of the Space Station, essential to its utility for science, commerce, and technology, is the continuing presence of its crews. Men and women will be aboard the Space Station base full-time. The potential of humans--their resourcefulness and creativity--is unique and essential. The Space Station will be designed to exploit these human capabilities. The Space Station's microgravity environment and extended time in orbit will enable scientists to make new discoveries in materials research and life sciences. Moreover, the Space Station's external structure is designed to be a stable platform that will be available for mounting a number of specialized instruments and telescopes. Scientific instruments, whether in a laboratory or on a boom, require maintenance, upgrading, repair and replacement. The Space Station will make extensive use of telerobotics to meet these requirements. The SSF will be designed to evolve and to be capable of growth in its capabilities so that future needs and challenges can be met.

The SSF will be a multipurpose, international facility. In 1984, President Reagan invited the full participation of other nations. During the ensuing definition phase, Canada, member countries of the European Space Agency (ESA), and Japan worked closely with the United States to define their participation. These parallel definition and preliminary design studies have resulted in the identification of the Space Station elements to be developed by our partners. Negotiations with these international partners for the development phase of the program were completed in the fall of 1988. Agreements have been signed with the Canadian government for the development of a mobile servicing system and with the member countries of ESA for the inclusion of a pressurized attached module, a man-tended free flyer, and a polar platform. An agreement has also been signed with the Japanese government for the development of an attached laboratory module. In accordance with the terms of the agreements, the United States and the international partners will share the total available resources and the costs for its operation.

The basic configuration of the Space Station and its supporting elements is a result of a lengthy and iterative process involving NASA centers, U.S. industry, our international partners, and the national and international science communities. The current baseline is comprised of a single horizontal boom structure with 75KW of photovoltaic power, the U.S. laboratory and habitation modules, four resource nodes, two international laboratory modules (one European and one Japanese), and a Canadian mobile servicing capability. These elements comprise the manned base, and provide internal and external accommodations for the attachment of science and application payloads. The launch of the first SSF element is planned for March 1995. The U.S. Polar Platform continues under development, as does the ESA man-tended free-flyer as a co-orbiting platform with the manned base. Since the U.S. Polar Platform is now planned for the unique applications of the Earth Observing System (EOS), management is being transferred to the Office of Space Science and Applications (OSSA). Beginning in FY 1991, funding for the Polar Platform will be included in the Space Science and Applications program.

In addition to the development of the manned base, the Space Station program includes development of a Flight Telerobotic Servicer (FTS). The FTS will be a highly automated telerobotic device capable of precise manipulations in space. The FTS on board the Space Station will increase safety and productivity by reducing Extravehicular Activity (EVA) time, allowing the use of robotics for assembly tasks and hazardous tasks, and freeing crew members for scientific tasks. The FTS will play a key role in the further development of automation and robotics technologies which will be of benefit not only in space, but in ground-based applications such as manufacturing. Two precursor Shuttle flights in 1991 and 1993 will demonstrate this robotic technology in space prior to the availability of the FTS for the first element launch.

A key design objective of the Space Station is to enable hardware and software to evolve in response to increased user demands and the need for augmented operational capabilities. The achievement of this objective is dependent on the results of the research, studies, and advanced technical developments funded within Advanced programs (formerly Transition Definition). These include systems studies to define options for evolution of the Space Station consistent with potential agency missions such as journeys to the Moon and Mars, as well as technology development, primarily in automation and robotics, that will enhance Space Station productivity. These activities are essential for the long-term cost-effective utilization of Space Station Freedom and the preparation for future manned exploration.

Space Station operations encompass activities required to maintain the Space Station for its planned lifetime. This includes establishing an inventory of spares hardware, logistics support, crew training, mission operations, engineering support, launch processing, and user training and operations. Initial funding for this effort is included in the FY 1991 budget request.

In an ongoing effort to ensure development of the most productive and cost-effective station possible, the SSF program has completed a series of intensive reviews regarding program content and rationale, flight system configuration, and overall reasonableness of the total cost estimate. As a result of this review process, we believe we have achieved a configuration baseline and associated budget profile that will, over time, provide the infrastructure and capability for a premier permanently manned, long-term research facility in space.

In the last five years, the Space Station Freedom has faced nearly continual adjustment of its budget, has had a great deal of managerial turnover, and has experienced several configuration and schedule changes. In FY 1990, the President requested $2,050 million for Space Station and Congress appropriated $1,800 million. Following the allocation of both the general reduction specified in the appropriation and the reduction due to partial-year sequestration, the FY 1990 Operating Plan was established at a level of $1,749.6 million. Of this amount, $750 million will not be available until after June 1, 1990. One of the most important motivations in developing a plan within the FY 1990 appropriated amounts and in developing the FY 1991 budget request has been to stabilize program elements to the degree possible and to emphasize those design and development activities leading to first element launch. The second objective was to meet our commitments to the Station users, both the domestic community and our international partners. Constrained funding has, however, forced us to delay the provision of some Station capabilities until later in the assembly sequence. However, the first element launch is still March 1995, and the full baseline station will be on orbit at assembly complete.

This budget requests appropriations for the Space Station of $2,451.0 million for FY 1991, $2,907.0 million for FY 1992, and $3,031.2 million for FY 1993. These funding levels are required to support the schedule and capability commitments made to the Space Station Freedom users, our international partners, and the U.S. Congress. In addition to the specific funding levels, multi-year appropriations are being requested in order to provide a stable funding baseline for this highly complex national program. Agreement on these measures on the part of Congress and the Administration will provide increased program stability while maintaining cost control discipline for both development and operations. In addition, the Administration again plans to request legislation to establish a total development program cost ceiling of $13 billion, in FY 1984 constant dollars adjusted for inflation and private investment and involvement.

BASIS FOR FY 1991 FUNDING REQUIREMENT

DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Management and integration	187,700	230,200	198,258	248,000
Pressurized modules	155,500	366,000	303,900	522,100
Assembly hardware/subsystems	267,200	762,000	666,300	872,600
Platforms and servicing	51,200	130,000	107,500	34,100
Power system	124,000	298,000	249,925	367,900
Operations/utilization capability development	56,400	184,000	135,340	255,100
Total	842,000	1,970,200	1,661,223	2,299,800

OBJECTIVES AND STATUS

As a research facility in space, the Space Station Freedom will provide opportunities for significant advances in science, technology and commerce. It must be flexible yet durable in its capabilities, as the Station will be on orbit for many years. It must be operationally affordable for its success will be measured by its operational utility. The objectives of the program are: (1) to establish a permanently manned research facility in low-Earth orbit in the mid-1990's with the capability to evolve to meet future potential requirements; (2) to enhance mankind's evolving ability to live and work safely in space; (3) to stimulate technologies of national importance (especially automation and robotics) by using them to provide needed capabilities; (4) to provide cost-effective operation and utilization of continually improving facilities for scientific, technological, and operational activities enabled or enhanced by the presence of man in space; (5) to foster mutually beneficial international cooperation in space; (6) to create and expand opportunities for private sector activity in space; and (7) to enable evolution to meet future potential requirements and challenges.

Following completion of a three-year definition and advanced technology development phase, the development program was initiated in FY 1987. The selected revised baseline configuration includes a permanently manned Space Station, unmanned platforms, and the associated ground-based infrastructure. The major physical elements of the configuration to be developed by the United States include pressurized habitation and laboratory modules, with a shirt-sleeve environment for crew habitation and for conducting experiments under microgravity conditions; resource nodes linking the modules in which command, control, docking and

extravehicular activity (airlock) functions will be based; high power solar arrays; a truss structure featuring accommodations for attached payloads and the FTS; pressurized and unpressurized logistics elements; extravehicular capabilities; and, a polar platform carrying Earth Observing System (EOS) instruments to be developed under the Space Science and Applications program. The configuration includes elements provided by the program's international partners. These elements are the Japanese experiment module, which includes a pressurized laboratory, an exposed module for payloads, and a logistics module; the Canadian Mobile Servicing System; and, the ESA's pressurized laboratory, polar platform, and man-tended free-flyer. Management of the U.S. Polar Platform is being transferred in January 1990 to the Office of Space Science and Applications (OSSA) since it is planned for the unique applications of the EOS. The Space Station will be able to support a crew of eight and provide a total average power of not less than 75 kilowatts, using photovoltaic (PV) arrays.

The ground-based infrastructure needed for the development and operation of the Space Station includes the development of capabilities for systems engineering and integration, a distributed system for technical and management information transmission, software development tools, prelaunch processing, mission operations, engineering support, integrated testing, and payload operations support.

The responsibility to provide Space Station program policy and guidance as well as the appropriate interface to other NASA and government programs resides at NASA Headquarters. The Space Station Freedom Program Office (SSFPO), located in Reston, Virginia, has the responsibility of managing and integrating the day-to-day technical development of the entire program. During FY 1990, the system integration functions will be strengthened by moving a significant part of these activities to the largest work package centers, Marshall Space Flight Center (MSFC) in Huntsville, Alabama, and Johnson Space Center (JSC) in Houston, Texas. These centers have the in-house expertise to perform these critical tasks. The transfer of functions will be accomplished primarily by a redistribution of positions, rather than actual movement of civil servants. The four "work package" centers, who manage the hardware/software design and development, are MSFC; JSC; the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland; and the Lewis Research Center (LeRC) in Cleveland, Ohio. While not work package centers, the Kennedy Space Center (KSC) at Cape Canaveral, Florida and the Langley Research Center (LaRC) in Hampton, Virginia have key Space Station responsibilities. KSC has the responsibility for Space Station prelaunch processing and post-landing activities plus a major role in logistics planning and implementation. LaRC has played a role in defining Space Station program requirements and conducting independent assessments. NASA's development strategy for the Space Station deliberately precluded utilization of a single prime contractor. For a program of such extended duration as the Station, dependency upon one company was not viewed as being in the best interest of the government. Moreover, the work package approach better utilizes NASA expertise at the field centers and fosters greater competition among U.S. industry. An essential component of this strategy is that NASA will have the responsibility to perform the overall systems engineering and integration and program management. The SSFPO is being assisted in these program-wide management integration functions by a Technical and Management Information System (TMIS) contractor, a Space Station Engineering and Integration Contractor (SSEIC), and a Software Support Environment (SSE) contractor.

The TMIS effort, contracted with Boeing Computer Services, facilitates both program control and engineering by enabling the electronic transmission of information and providing a means of distributing, maintaining, and archiving controlled data throughout the program. Grumman Aerospace and its team, as the SSEIC, supports NASA in a variety of areas, including systems engineering and analysis, distributed systems integration, technical integration, element and launch package integration, user interface planning, and program management and control. The SSE system, contracted with Lockheed Missiles and Space Company, is designed to assure a standardized software development and maintenance environment, in order to minimize the development and cost risk inherent in the task of integrating flight and ground systems software developed by a variety of Space Station contractors. Boeing Aerospace and Electronics Company; McDonnell Douglas Astronautics Company; General Electric Company; and the Rocketdyne Division of Rockwell International are the work package prime contractors for the design, development and support of the components and systems comprising the permanently manned Space Station. During the early stages of the contract period, the prime contractors began planning for the initiation of their respective work package preliminary design and development efforts. They also supported the work package centers in the evaluation of the Program Requirements Review (PRR) and participated in the planning and working groups that have been formed to allow the various program elements and participants to share information. Due to the complexity of this enormous effort, it soon became apparent that a mechanism was needed which would allow the prime contractors to work together to achieve the common goal of building the Space Station to specification, on schedule, and within the available funding. To satisfy this need, the Space Station program instituted associate contractor agreements among the contractors. They will have the responsibility, with NASA work package center and SSFPO oversight, for coordinating the integration of their efforts in a timely and cost-effective manner and for delivering to NASA the required integrated hardware and software.

The development program also includes critical supporting development activities at the four NASA work package centers, and the development of the capability to operate and utilize the Space Station. Work package supporting development includes design engineering, hardware integration and test capabilities, and assembly and checkout test capabilities; the provision of government furnished equipment (GFE); research and development (R&D) facility outfitting; and engineering management and analysis. These efforts support all of the work package prime contractors as well as overall NASA system engineering and integration efforts.

The Operations and Utilization Capability Development (OUCD) activities support major operational facility development and outfitting at the NASA work package centers and KSC. These facilities are critical to the integration, pre-launch/post-landing processing, and the missions operations and crew training of the Space Station systems.

Due to budgetary constraints, Space Station development activities will build up at a slower pace than previously planned. The program-level man-tended configuration preliminary design review (PDR), which will provide an evaluation of the design approach of the work packages, will slip from August 1990 to December 1990. Preliminary design reviews of major hardware elements and subsystems are being conducted during 1990, leading up to the program-level PDR. Successful completion of PDRs results in the readiness to proceed with detailed design of the SSF flight and ground hardware and software. The program-level critical design review (CDR) is currently planned to occur in FY 1992. The first element launch is planned for March of 1995, man-tended capability in the third quarter of 1996, permanent manned capability is planned in the fourth quarter of 1997, and assembly will be completed in the fourth quarter of 1999.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Management and integration..............	187,700	230,200	198,258	248,000

OBJECTIVES AND STATUS

Elements of the SSF are being designed and developed by NASA centers and contractors throughout the United States as well as by the Canadians, Europeans, Japanese, and their contractors. Coordinating and integrating all these various activities requires a comprehensive management and integration effort by the SSFPO. Management responsibilities include: overall program management and direction; systems engineering and design; management of technical and administrative information; systems software environment design and development; safety, reliability, maintainability, and quality assurance activities; and integration of the United States and international systems and elements.

The broad scope and large magnitude of the Space Station program requires that NASA be supported by contractors knowledgeable in overall systems design, engineering, and integration. To achieve this goal, NASA awarded a program support contract to Grumman Aerospace Corporation, Bethpage, New York. Grumman has responsibility for supporting overall Space Station systems engineering and integration activities. Grumman supports the SSFPO in Reston, Virginia, and the system integration activities at JSC and MSFC, as well as providing support to the work package centers and KSC to assist them in their program activities. This includes providing the engineering manpower necessary for total systems configuration analysis and integration, design trade-offs, and operational analyses. They also assist in evaluation of technical performance across the program and perform program schedule integration. They develop technical plans and procedures for the verification, assembly, and integration of the overall Space Station system and assist in the assessment of hardware/software systems developed by the work package prime contractors. During FY 1990, they will play a significant role in all of the activities necessary for preparing and supporting the PDR. The man-tended configuration PDR is scheduled for late December 1990. A plan has been initiated to transition engineering and management personnel with extensive Shuttle experience into key Space Station positions. In addition, the program system integration activities have been strengthened by moving a significant element of these tasks to the largest work package centers -- Johnson Space Center (JSC) and Marshall Space Flight Center (MSFC). These offices will be managed by the SSFPO utilizing on-site personnel including Grumman.

Implementation of a program-wide technical and management information system (TMIS) is a significant part of the management and integration activity. The size and complexity of technical and management information that must be shared across all elements and levels of the program requires the development of an advanced information system that can expeditiously handle the flow of these data. Boeing Computer

Services was awarded a systems integration contract to provide the official repository of technical and management information. It provides a common methodology for tracking, updating, and disseminating program documentation. TMIS facilitates and provides electronic transfer of a variety of program data among all the participating NASA centers and contractors. It will also allow NASA to electronically transfer appropriate program data to compatible information systems of the international participants. The initial increment of TMIS hardware and software has been delivered and work on populating the data bases to be used in the program has begun. The computer-integrated engineering capability will be put into place this year to support upcoming program milestones.

Another important component of the management and integration effort is the design, development, and application of compatible flight and ground support software. To ensure compatibility across the various elements of the Space Station information system, NASA awarded a contract to the Lockheed Missiles and Space Company for the development of a software support environment (SSE). Lockheed is tasked to develop the software tools, rules, and standards that will be common to all Space Station flight and ground support users in their software development efforts. SSE has developed the initial SSE development facility which is providing basic software life cycle support capability. Five software production facilities are in place at the work package sites supporting their software development activities.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction in the management and integration funding of $31.9 million from the FY 1990 budget request. The configuration budget reviews conducted this past summer recommended that the three principal contracts in the management and integration budget (TMIS, SSE and SSEIC) remain fairly constant with the FY 1989 level of funding, rather than being allowed to grow as previously planned. These three contracts account for most of the decrease from the budget estimate. Several additional areas including the independent assessment of program requirements and systems engineering and integration support have been reduced.

BASIS OF FY 1991 ESTIMATE

The SSEIC will be assisting NASA in developing integrated schedules, verification plans, interface control documentation, and engineering data bases. Also during this period, the SSEIC will provide engineering support to the development of program plans for launch package integration, on-orbit assembly and checkout, integration with the Space Shuttle, design reference mission and mission integration, and system safety and quality assurance program planning. This critical system engineering effort will be in support of the program office and the program integration offices at each work package center and at KSC.

The SSE will build upon its initial operational capability by increasing and improving existing capabilities in the Software Support Environment Development Facility (SSEDF). The software production facilities at the field sites will be supported and additional facilities put in place as requirements dictate.

TMIS will continue to incrementally deliver its products and will work closely with all levels of the program to assure the most efficient and comprehensive exchange of information. Efforts will continue towards completion of the various bridges needed to electronically link together the contractors, NASA centers, users, and international partners as well as provide training to TMIS users as the system evolves. Technical and resource information management, tracking systems and data bases will continue to be developed with emphasis on the efforts needed to support the program PDR process. Future increments will focus on integrating data bases containing both technical and management data. The first delivery of computer integrated engineering (CIE) capability for the program will be operable in mid-FY 1990 and considerable effort will be required to prepare the engineering data bases with current information to support the program design reviews as well as to train program personnel.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Pressurized modules - Work Package 1, Marshall Space Flight Center...........	155,500	366,000	303,900	522,100

OBJECTIVES AND STATUS

Major components of Work Package 1 include the U.S. laboratory, habitation and logistics modules; nodes structures; airlock systems; environmental control and life support system (ECLSS); internal audio, internal video and internal thermal systems; fluid management systems; module outfitting; and associated software development.

Work Package 1, managed by MSFC in Huntsville, Alabama, has as its prime contractor, Boeing Aerospace and Electronics (BAE). Assisting BAE as major members of the prime contract team are Teledyne Brown Engineering (Huntsville, Alabama), Lockheed Missiles and Space Company (Sunnyvale, California), and Grumman Aerospace Corporation (Houston, Texas). Non-prime (supporting development) activities include data support services, product assurance, and project support.

Since the initiation of the development phase of the SSF Program, emphasis has been placed on the preparation of the plans and procedures that will be needed to design, develop, build, test, integrate, launch, and operate the Station. These plans and procedures have been updated with the results of the recent configuration baseline review (CBR) activity and have been baselined. These program documents will serve as the basis for the preliminary design review which will occur in the first quarter of FY 1991.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction in pressurized module funding of $62.1 million. Prime contractor activities decreased by $46.9 million following the CBR; the major changes consist of the opening of the ECLSS loop until assembly complete, the deletion of lab support equipment, the rephasing of the washer, dryer, and dishwasher to coincide with the planned support of a crew of eight, the deferral of the project preliminary design reviews and critical design reviews for the habitation and logistics modules, and the deletion of a ground computer that would separately house BAE's computer-aided design system from their information management system. Supporting development was reduced by $15.2 million. Selected materials analysis tasks were deleted; and, data support services, program support, and systems engineering and integration were descoped.

BASIS OF FY 1991 ESTIMATE

The preliminary design review (PDR) will occur in FY 1991 and will be preceded by project PDR's in Work Package 1 for many of its major systems and elements. The work package major activities for FY 1991 include, in the ECLSS area, the procurement of hardware for both developmental and qualification tests to occur during the fiscal year, along with the integration activities between the hardware and software. In the structures area, development tests will be completed after which procurements for node flight hardware, the first structure element delivery, will begin. In the U.S. laboratory area, final flight article drawings will be initiated and the process materials management system (PMMS) subcontractor PDR will occur. The development hardware for the PMMS will also be procured during this time period.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Assembly hardware/subsystems - Work Package 2, Johnson Space Center........	267,200	762,000	666,300	872,600

OBJECTIVES AND STATUS

Work Package 2 responsibilities include the integrated truss assembly, mobile transporter, airlock structure and unique equipment, outfitting of the resource nodes, and the propulsion system. Also included in Work Package 2 are the data management system (DMS), communications and tracking (C&T), guidance, navigation and control (GN&C), extravehicular activity (EVA) systems, external thermal control systems (TCS), mechanical systems, fluids, and utilities distribution.

Work Package 2, managed by Johnson Space Center (JSC) in Houston, Texas, has as its prime contractor, the McDonnell Douglas Corporation (MDAC). Assisting MDAC as major members of the contract team are IBM (Houston, Texas and Owego, New York), Lockheed Missiles and Space Company (Houston, Texas and Sunnyvale, California), General Electric/RCA Corporation (Camden, New Jersey), Honeywell (Clearwater, Florida), and Astro Aerospace Corporation (Carpinteria, California). Non-prime (supporting development) activities include structural analysis, manned systems analysis, EVA planning, product assurance and project management support.

Much of the effort since inception of the development phase has been in formulating the plan, procedure, and design concepts that will be utilized for the development of the Work Package 2 elements and systems. The configuration baseline review (CBR), which was completed in mid-FY 1989, laid the groundwork for finalizing the program requirements to proceed toward the preliminary design review (PDR).

The FY 1990 activities focus on completing the system and element PDR's in support of the program level PDR, which is to occur in the first quarter of FY 1991. Leading up to the PDR, software requirements reviews will occur in the first two quarters of FY 1990. Work is continuing to progress in the development of test beds for evaluation of design concepts, design and trade studies, facility requirements, and subsystem requirements. Subcontractors are in the process of selecting vendors for subsystem components. JSC personnel have been working with the Canadians to coordinate their mobile servicing center with the mobile transporter. Plans for the procedures, hardware, and software needed for on-orbit assembly are continuing and Shuttle/Station docking concepts are being investigated and tested. Also ongoing is the design and development of the flight experiments that will be needed to test various concepts and hardware prior to their use on the SSF. These Shuttle flight experiments will, among other things, test thermal systems and EVA mobility aids for assembly and maintenance.

CHANGES FROM FY 1990 BUDGET ESTIMATE

As a result of reduced funding the assembly hardware and subsystems budget estimate was reduced $95.7 million. Prime contractor activities were reduced by $42.0 million. The Space Station unique EVA suit was deleted, as was the development of common hardware for the polar platform, the global positioning system and space-to-space KU-band communication system were deferred, and data management system hardware was reduced. Supporting development tasks decreased $53.7 million. Reductions were achieved by descoping communication and tracking work, rephasing optical system and resistojet work, deleting activity supporting the Station-unique EVA suit, and reducing project management support.

BASIS OF FY 1991 ESTIMATE

A major milestone in FY 1991 is the first of the system critical design reviews (CDR) for the DMS. The first delivery of a DMS kit to the McDonnell Douglas/JSC software production facility also occurs in this year for use in the initial verification of ground and flight DMS software. Engineering development units for the mobile transporter, the assembly work platform, the astronaut positioning system, the C&T system, the hyperbaric hatch, and the TCS will be completed and testing will begin to support CDR. The prime contractor will also continue to support the various working groups and panels that are responsible for coordinating the efforts of the program participants and will perform studies as directed by JSC and the SSFPO.

JSC will also continue supporting development efforts in preparation for the CDR. The various test beds will be updated with higher fidelity flight-like hardware to support prime contractor detailed design activity and CDR. For example, DMS kits are installed in the DMS test bed and contractor-supplied antennas will be tested for compatibility in the C&T labs. Efforts will continue in preparation for the Shuttle thermal flight experiments.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Attached Payloads Equipment, Polar Platform, and servicing - Work Package 3, Goddard Space Flight Center.	51,200	130,000	107,500	34,100

OBJECTIVES AND STATUS

Work Package 3 includes the design and development of the free-flying, unmanned U.S. polar platform (through 1990) and the attached payload accommodation equipment (APAE) for the mounting of various scientific instruments on the manned base. A key component of this work package is an ongoing interaction with potential users of the Space Station. Understanding the needs of potential Space Station users and including them in all of the pertinent planning activities is vital to the design, development, and operation of the Station.

Work Package 3, managed by Goddard Space Flight Center (GSFC), Greenbelt, Maryland, has as its prime contractor, the General Electric Company, Astrospace Division, Valley Forge, Pennsylvania, and East Windsor, New Jersey. The TRW Corporation of Redondo Beach, California is the major subcontractor to General Electric. Non-prime (supporting development) tasks include systems engineering and integration, platform and APAE design validation, and management and integration.

Since the polar platform is now planned for the unique applications of the Earth Observing System (EOS), management of the platform is being transferred to the Office of Space Science and Applications (OSSA) in early 1990. The decision to make this transfer was made late in 1989 after it was determined that the required capabilities of the platform could be achieved in a more cost-effective manner by designing the platform to meet the unique requirements of the EOS. To meet these unique requirements, the platform does not require a substantial level of hardware, software, and procedures commonality with the manned base. Therefore, NASA concluded that the Polar Platform project should be managed with the EOS instrument development. Of the $51.2 million for Work Package 3 displayed in the FY 1989 column, $17.3 million was allocated for the polar platform development. ($3.1 million of operations/utilization capability development funding in FY 1989 was also attributable to supporting the platform.) The FY 1990 budget request of $130 million included $75.3 million for the platform, and the FY 1990 current estimate is $74 million. Beginning in FY 1991, the funding for the Polar Platform project is being budgeted by OSSA. The Space Station funding was reduced in FY 1991 and a corresponding amount added to the OSSA funding request to accommodate this transfer of responsibility.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $22.5 million. Prime contractor activity was reduced by $12.0 million, and supporting development decreased by $10.5 million. The content deleted affected the attached payloads accommodations and included the payload pointing system, active cooling, the contamination monitoring system, attitude determination system and servicing. Additionally, the polar platform planned flight was changed from a generic platform design based upon commonality with the manned base to a unique design to accommodate the EOS program. Reductions to funding for the prime contractor effort were consistent with appropriations direction and the sequestration.

BASIS OF FY 1991 ESTIMATE

A major activity taking place within Work Package 3 during FY 1991 is the preliminary design review (PDR) for the APAE. Upon successful completion of the PDR, detailed design, testing, long-lead procurement, and fabrication will begin. Supporting development activity at GSFC will include continuing engineering and discipline support. As part of the thermal program, development of a data management test bed, and the Space Shuttle thermal flight test experiments will continue.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Power system - Work Package 4, Lewis Research Center........................	124,000	298,000	249,925	367,900

OBJECTIVES AND STATUS

Work Package 4 provides for the development of the Space Station Freedom's electrical power system. This encompasses the development of photovoltaic (PV) power modules to collect power and a power management and distribution (PMAD) system to distribute an average of 75 kilowatts of power for Station use. Preliminary development of a solar dynamic power system will continue through FY 1991 to preserve this option for future growth.

Work Package 4, managed by the Lewis Research Center (LeRC) in Cleveland, Ohio, has as its prime contractor, the Rocketdyne Division, Rockwell International Corporation (Canoga Park, California). Supporting Rocketdyne as major members of the contract team are Ford Aerospace (Palo Alto, California); Harris Corporation (Melbourne, Florida); Allied-Signal Aerospace Corporation (Tempe, Arizona); and Lockheed Missiles and Space Company (Sunnyvale, California). Non-prime (supporting development) activities include PV and PMAD evaluation and analysis, systems engineering and integration, and project management support.

The electric power system is an essential component of the first SSF element launch, requiring accordingly early hardware readiness. System and subsystem design and development are actively being performed by the contractor team and by the LeRC supporting development personnel. Component testing of the batteries and solar cells began in FY 1988 and will continue into FY 1990 in preparation for the preliminary design review. Test beds for both PV power and the PMAD system have been developed and are being utilized. Construction of the Space Power Electric Lab (SPEL) at Rocketdyne is complete and testing will begin in FY 1990. The Power System Facility (PSF) at the LeRC and the Space Power Facility (SPF) managed by LeRC are being prepared for testing of flight design hardware. The PSF will be operational in FY 1990. The SPF will be operational in FY 1992.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $48.1 million, of which amount the prime contract was reduced by $46.9 million and supporting development by $1.2 million. This reduction has been accomplished primarily by changing the power management and distribution system from an alternating current (AC) system to a direct current (DC) system. The FY 1990 estimate also reflects the addition of a simpler single-phase thermal control system (TCS) for the PV module, which replaces the more complex two-phase TCS.

BASIS OF FY 1991 ESTIMATE

During FY 1991 the pace of hardware design and development activities will intensify. Following the program preliminary design reviews, Rocketdyne will continue with development and qualification of the solar cells and blankets. Energy storage assembly qualification cells will be fabricated and tested. Detailed design and testing of module items such as beta gimbals and electrical equipment assemblies will continue as will the preliminary design effort for the solar dynamic power module. PMAD components and orbital replacement units will undergo detailed design during FY 1991 and development and testing of brassboard and engineering model components will continue. End-to-end testing of PMAD components in the SPEL will be completed in late FY 1991. Hardware will be delivered to LeRC in preparation for the Electrical System Integrated Test (ESIT), scheduled to begin in the PSF in early FY 1992.

Supporting development activities complement those being performed by the contractor and include the independent verification of the prime systems engineering and integration efforts. NASA also provides for an operational facility that will be utilized by the prime contractor to conduct "Fleet Leader" battery testing, electrical integrated testing, and system validation of the PV module. Also included in supporting development is the design and provision of the interfaces with the SSE and the Space Station Information System. Key activities include continued utilization of the existing PV/PMAD DC test bed for component and systems testing.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Operations/utilization capability development...........................	56,400	184,000	135,340	255,100

OBJECTIVES AND STATUS

The purpose of the Operations/Utilization Capability Development (OUCD) program is to develop a set of operational facilities, systems, and capabilities to conduct the operations of the Space Station Freedom. The majority of the work will be performed at KSC, MSFC, and JSC, although key operational capabilities will be developed at other NASA centers. KSC will develop launch site operations capabilities for conducting prelaunch and post-landing ground operations for the SSF. These capabilities will include the development of the Test, Control and Monitor System (TCMS) to provide real-time checkout, control and monitoring functions during processing of Space Station elements at KSC prior to launch. Prelaunch and post-landing ground operations will occur in the Space Station Processing Facility (SSPF) and other key facilities, including the Space Station Hazardous Processing Facility (SSHPF) at KSC.

MSFC will develop user integration capabilities to establish user requirements and perform user operations support. Efforts will include the development of the Payload Operations Integration Center (POIC) and the Payload Training Complex (PTC), as well as extensive payload mission planning and analytical integration. The major objective at JSC is to develop space systems operations capabilities for conducting training and on-orbit operations control of the Space Station. Efforts will include the development of the Space Station Control Center (SSCC), the Space Station Training Facility (SSTF), and the Operations Planning and Analysis System (OPAS). LeRC will provide an engineering support center for the power system, GSFC will provide one for attached payloads, and MSFC will provide one supporting its major flight hardware elements and systems.

Work is currently underway to develop facility requirements and outfitting needs and to develop the mission planning and user interfaces. The prime contractors associated with the four work packages are assisting in these activities since the design, development, and operation of the Station are so strongly interconnected. User input is being solicited and they are being kept informed of progress in all of the OUCD planning efforts. Astronauts are also included in this process with their input a key element of the design and operations activities.

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CHANGES FROM FY 1990 BUDGET ESTIMATE

The FY 1990 budget estimate was reduced by $48.7 million. This reduction has been taken by delaying outfitting of the KSC processing facility (SSPF), and adopting an incremental, phased approach to the capabilities required for the SSCC, SSTF, POIC and PTC. This restructuring is designed to provide initial capabilities in the first years of the Station and the full-up capabilities in the assembly complete time-frame. Additionally, the concept of an engineering support center has been redefined to require a much lower level of support and capability than had been assumed earlier. Also, the buildup of manpower at KSC was considerably slowed, as was the manpower buildup for increment design, operations planning, and procedures development efforts at JSC.

BASIS OF FY 1991 ESTIMATE

At MSFC, the refined operational requirements for the POIC will be baselined, a request for proposal for the PTC systems procurement and development will be released and work will continue on the mission planning system (MPS) development. Consolidated operations/utilization plans for the habitation and laboratory modules will also be completed.

At JSC the requirements definition and design of the training facility (SSTF) and control center (SSCC) should reach the final stages of the design process and hardware/software development of those facilities will be initiated. Software development activities for the Operations Planning and Analysis System (OPAS) will also continue at an increased pace as will the operations concepts and planning/procedures development effort.

LeRC and GSFC will continue the design of their engineering support facilities and provide low levels of support to the operations and utilization planning efforts of the program.

At KSC, funding provides for increased activity in planning, scheduling, systems software development, as well as equipment and manpower for the TCMS and SSPF. The TCMS PDR and the logistics information system CDR are planned for completion. The facilities requirements document will be baselined for the hazardous processing facility.

BASIS OF FY 1991 FUNDING REQUIREMENT

FLIGHT TELEROBOTIC SERVICER

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Flight telerobotic servicer.............	46,000	15,000	79,400	106,300

OBJECTIVES AND STATUS

The Flight Telerobotic Servicer (FTS) will be a highly automated robotic flight system capable of precise manipulations in space. It can be operated by astronauts at work stations aboard the Space Station or the Shuttle by direct manipulator control. Its hardware and software will be modular to ensure serviceability, and its configuration will be flexible to accommodate technological upgrades and growth to autonomous operation. The FTS will be capable of performing EVA tasks such as assembly, inspection, maintenance, and servicing. By reducing dependence on EVA, it will improve crew safety and enhance crew utilization. The FTS will be designed to attach to several hardware elements, such as the Shuttle's Remote Manipulator System, utility ports along the SSF truss, the Canadian Mobile Servicing Centre (MSC), and SSF platforms. The knowledge NASA gains using the FTS in space will facilitate the transfer of automation and robotics (A&R) technology to U.S. industry.

Project management is the responsibility of GSFC, with support from other NASA centers and contractors. The major elements of the program include the Space Station FTS (SSFTS), or flight telerobotic servicer flight unit, which will be available at first element launch (FEL), the engineering development hardware supporting the Shuttle Development Test Flight (DTF-1), the advanced development hardware and software required for the Shuttle Demonstration Test Flight (DTF-2), and the ground-based Engineering Test System (ETS). Supporting activities at GSFC and other NASA centers are developing automation and robotics technologies to meet FTS requirements, improve performance, and support the transfer of demonstrated capabilities and technology concepts to commercial applications.

The DTF-1 hardware is planned to be flown aboard the Space Shuttle in late 1991 and will consist of a telerobotic manipulator, a carrier structure, task elements, and a workstation. Using existing technology, DTF-1 will evaluate FTS design approaches and man-machine interfaces. In September 1988, nine-month letter contracts for $4.5 million each were awarded to the Martin Marietta Corporation and to

Grumman Aerospace for preliminary design of DTF-1. These contracts provided for initiation of long-lead procurement items and for delivery of all analyses and documentation required to support a PDR for DTF-1. Martin Marietta Astronautics Group of Denver, Colorado was awarded the FTS Phase C/D contract in July 1989 and completed the DTF-1 PDR also in July 1989. A delta PDR will be held in January 1990, followed by the DTF-1 CDR in April 1990.

The DTF-2 hardware will consist of a more mature version of the SSFTS, a carrier structure, task elements, flight support equipment, and a workstation to be flown aboard the Shuttle in late 1993. DTF-2 will demonstrate FTS capabilities prior to SSF deployment.

The ETS will be a ground test system for FTS software development and verification; for dexterous task planning and verification; and for flight anomaly investigation. It will consist of a telerobot, multipurpose end-effectors and tools, ground support equipment, and spares.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The FY 1990 budget estimate assumed that the FTS would be a commercially developed system, therefore the request only provided for supporting development activities. After careful consideration of industry responses a decision was made that the FTS was not a viable candidate for full commercial development.

The FY 1990 budget estimate was increased by $64.4 million, consistent with the appropriations decisions, to provide for a NASA procurement through a prime contractor and to enable an early demonstration flight on the Space Shuttle.

BASIS OF FY 1991 ESTIMATE

The requested funding will provide for the continued development and test of the SSFTS, the integration and launch of the DTF-1, and to initiate evolutionary enhancements to the baseline SSFTS design.

Launch of the DTF-1 is planned for FY 1991 on a very challenging schedule. Initial delivery of the DTF-1 training system and simulator will begin in mid-FY 1990 and will be available for astronaut training efforts. The DTF-2 PDR will occur in early FY 1991, and the SSFTS PDR will occur before the launch of the DTF-1. The DTF-1 hardware testing, and particularly the software developed for the DTF-1, will be a major emphasis in FY 1991.

Supporting development activities in FY 1991 include crew training, flight operations support, and integrated flight simulations. Efforts will continue on applications procedure development, and technology assessment and testing.

BASIS OF FY 1991 FUNDING REQUIREMENT

OPERATIONS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Operations	--	25,000	--	8,900

OBJECTIVES AND STATUS

Planning for operations and utilization has been an integral part of the SSF design and development program and a major driver in the approached established for Station assembly, utilization, and evolution. As a long-term permanently manned laboratory in orbit, Freedom will be serving the needs of many disciplines and individuals, and must be designed and operated to be safe, reliable, and accommodating to these numerous diverse users. It must also be cost-effective to operate, economical to utilize and amenable to changes in technology that will be occurring during its planned 30 years in space. The various elements of the development program such as flight systems hardware/software production, operations/utilization capability development, and management and integration will transition, over time, into the components of the operations program. These components include flight and ground hardware and software sustaining engineering, integrated logistics support, user integration and operations support, space system operations support, pre-launch and post-landing operations, and information systems services operations.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects the deletion of the $25 million requested in the budget. The first year for funding of Operations has been delayed to FY 1991 as a result of the program rephasing associated with the rebaselining activities of the configuration baseline review. A key element of this change was an analysis of the lead times for initial spares, which indicated FY 1990 resources would not be required in order to meet the revised program milestones.

BASIS OF FY 1991 ESTIMATE

Initial lay-in of spares for both flight hardware and ground support equipment (GSE) is a major element of the operations funding. Procurement of the long-lead materials for components required for GSE and flight spares production will be initiated in FY 1991 so that spares will be available to support launch site processing and on-orbit operations.

BASIS OF FY 1991 FUNDING REQUIREMENT

ADVANCED PROGRAMS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Advanced programs	12,000	25,000	9,000	36,000

OBJECTIVES AND STATUS

The National Space Policy states that the "Space Station will allow evolution in keeping with the needs of Station users and the long-term goals of the United States." This policy encapsulates the goal of Advanced programs and reaffirms the NASA approach to the Space Station Freedom program since its inception: to design and build a facility that is capable of expanding original capabilities, adding new functional capabilities, and incorporating improved technologies. The Space Station Freedom design must reflect consideration of an extended operational lifetime in support of a changing and growing user community. New impetus is given to these emphases by the President's request for a plan for the Human Exploration Initiative.

Advanced programs, formerly referred to as "Transition Definition," has three elements: advanced system studies, advanced development and support for human exploration. The thrust of these elements is to understand and enable future evolution of Space Station Freedom beyond the currently approved baseline. The advanced studies focus on critical design provisions required of the baseline program configuration, in order to accommodate identified mission drivers. The studies also determine long-range technology needs and associated maturity dates to steer the advanced development program. The advanced development focus is on near-term improvements in productivity and reduced operations costs through the application of automation and robotics to flight and ground systems. As with advanced system studies, particular emphasis is placed on identifying design impacts to the baseline configuration and systems. In the advanced programs budget, support for human exploration focuses on those capabilities required for an enhanced Space Station to support potential manned missions to the Moon and Mars.

The specific objectives of the advanced system studies are to define: (1) Space Station growth concepts, (2) systems requirements, (3) preliminary designs to support the Mission to Planet Earth studies and the continued growth of a multidisciplinary Space Station, (4) long-range technology needs, and (5) design accommodations in the baseline program to preserve the capability for evolution and the incorporation of new technology.

The specific objectives of the advanced development activities are: (1) to enhance baseline Freedom capabilities with an emphasis on increasing productivity and reliability through the use of automated systems and robotics (e.g., remote manipulator system and FTS); (2) to reduce operations costs; and (3) to enable Space Station Freedom evolution by providing mature technology in areas required to support day-to-day operations and advanced missions.

Examples of activities in support of human exploration are the assessment and preliminary design of a new space suit with advanced capabilities, solar dynamic power, and alternative reaction control propulsion systems.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The FY 1990 budget estimate for Advanced Programs has been reduced by $16.0 million. The advanced development tasks will take the largest share of the reduction. The major tasks deferred include verification and validation tools for expert system software; optical disk data storage system prototype; advanced user-payload interface and control (Telescience) prototypes; crew/equipment retrieval robot experiment; and expert systems to detect faults in the on-board systems, including communications and tracking, guidance navigation and control, Space Station Remote Manipulator System, and extravehicular activity systems. Critical advanced systems studies will continue, but at a significantly reduced level.

BASIS OF FY 1991 ESTIMATE

The key FY 1991 activities in advanced system studies and advanced development are directly related to the program PDR's. It is crucial that the evolution performance requirements and corresponding design solutions, i.e., "hooks and scars," defined in FY 1990 are incorporated into the program. These design provisions will be evaluated at Levels I, II, and III Change Boards.

During FY 1991, advanced system studies will build on previous work by continuing the definition of established evolution reference configurations at the Phase-A level. These studies will include operations analyses to establish the systems-level implications for the evolution of Freedom operations and utilization, particularly in the potential role of transportation node for exploration mission support.

The advanced development program for FY 1991 has three major areas: continued flight and ground systems embedded automation; telerobotics; and software tools and processors. Tasks under flight and ground systems address the application of knowledge-based systems (KBS) technology to on-orbit system control, ground operations support, and the Space Station information systems. These tasks are aimed at understanding the "hooks and scars" associated with the application of KBS techniques to thermal, electrical power, reaction control, health maintenance, scientific experimentation, data management, command and control, and environmental control and life support systems. Telerobotics tasks are focused on improving operator effectiveness and productivity by permitting ground-based teleoperation of Space Station Freedom robotic systems, and by increasing robot autonomy and the development of associated software/hardware. Tasks related to software tools and processors address advanced automation software development, advanced computational hardware and environments, human factors, and systems integration. Systems engineering issues common to all three major areas in advanced development include the integration of KBS applications with conventional automation techniques; requirements for on-board high speed data processing, storage, and communications capacity; software development, testing, and maintenance; and the identification of the boundaries of KBS performance in terms of execution speed and application complexity.

In support of human exploration, $20.0 million of the total of $36.0 million will enable assessment and preliminary design of: (1) a high pressure space suit (to minimize prebreathing requirements) which is serviceable on-orbit, to support Station-based EVA's; (2) solar dynamics power and the associated hybrid power distribution system; and (3) an advanced propulsion system, with higher specific impulse, to keep propellant logistics requirements at an acceptable level for the Station. The advanced space suit appears required due to the projected requirements for frequent EVA's to support in-orbit assembly of Exploration vehicles. Preliminary study results also indicated that a significant power increase would be required associated with Space Station operations supporting an Exploration program. The increased power demand would probably be met by installing solar dynamic power modules and modifying the power distribution system. In propulsion, the number of reaction control and reboost events for Space Station operations while the SSF operates as a transportation mode could cause a significant increase in logistics support flights if the baselined hydrazine system were retained. Analysis of the logistics requirements and evaluation of alternative propulsion systems will be pursued.

BASIS OF FY 1991 FUNDING REQUIREMENT

ORBITAL DEBRIS RADAR

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Orbital debris radar.....................	--	15,000	--	

CHANGES FROM FY 1990 BUDGET ESTIMATE

Funding for the development of the orbital debris radar is provided under Construction of Facilities, consistent with the FY 1990 appropriation action.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT SPACE

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Spacelab	87,600	98,900	95,600	130,700	RD 2-5
Upper stages	131,600	88,600	84,600	91,300	RD 2-8
Engineering and technical base	160,600	189,800	181,600	218,500	RD 2-10
Payload operations and support equipment	60,700	81,100	66,700	122,500	RD 2-13
Advanced programs	52,700	48,700	33,600	53,200	RD 2-15
Advanced transportation technology	81,400	5,000	(10,500)	53,900	RD 2-18
Tethered satellite system	26,400	19,900	24,000	17,900	RD 2-20
Orbital maneuvering vehicle	73,000	107,000	76,281	85,400	RD 2-21
Total	674,000	639,000	562,381	773,400	

Distribution of Program Amount By Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	149,100	180,200	158,900	243,100
Kennedy Space Center	80,200	88,800	86,500	117,200
Marshall Space Flight Center	396,200	290,900	287,781	312,000
Stennis Space Center	11,200	5,800	5,600	6,100
Goddard Space Flight Center	10,600	6,400	5,900	9,800
Jet Propulsion Laboratory	2,200	1,200	300	500
Langley Research Center	2,500	1,400	600	1,400
Lewis Research Center	1,100	1,800	400	6,500
Headquarters	20,900	62,500	16,400	76,800
Total	674,000	639,000	562,381	773,400

OFFICE OF SPACE FLIGHT — SPACE TRANSPORTATION PROGRAM

OBJECTIVES AND JUSTIFICATION

The principal areas of activity in Space Transportation Capability Development include the operation of the Spacelab systems and related development activities; procurement of Upper Stages required to place satellites in high altitude orbits; the Engineering and Technical Base support at the manned space flight centers; Payload Operations and Support Equipment for accommodating NASA payloads; Advanced Programs study and evaluation efforts; Advanced Launch Systems efforts including definition and propulsion technology development to support potential heavy-lift capabilities and Advanced Transportation Technology in support of the President's Human Exploration Initiative; the design and development of the United States/Italian Tethered Satellite System; and the development of the Orbital Maneuvering Vehicle (OMV).

Spacelab and the Spacelab carrier systems were developed jointly by NASA and the European Space Agency (ESA). The Spacelab is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The Spacelab carrier systems includes pallets which provide payload mounting and support services (pointing, computer control, data processing, power, cooling, etc.). The Spacelab and carrier systems development program continues with a recertification program to insure flight safety, the procurement of flight hardware to support the flight program, and necessary modifications including replacing the onboard computer system, verification of the cross-bay Hitchhiker and Spacelab Pallet System, upgrading obsolete Spacelab hardware to current technology and to possibly support Space Station experiment precursors.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle or core stage expendable launch vehicles alone. The program provides for procurement of stages for NASA missions, for technical monitoring and management activities for government and commercial Upper Stages, and a solid rocket motor integrity program to improve the technical understanding and build an engineering data base for solid motors.

The Engineering and Technical Base provides the core capability for the engineering, scientific, technical and Safety, Reliability and Quality Assurance (SR&QA) support required at the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the Stennis Space Center (SSC) for research and development activities. Additional requirements above the core level of capability are funded by the benefiting programs.

The Payload Operations and Support Equipment program develops and places into operational status the ground and flight systems necessary to support the NASA STS payloads during prelaunch processing, on-orbit mission operations and, when appropriate, post-landing processing. Included within this program area are the STS optional services for NASA payloads, integration activities for the Shuttle and Space Station including development of a docking module, and multi-mission payload support equipment.

Advanced programs conducts concept feasibility studies, selected system definitions and preliminary design (Phase B) studies, and undertakes related high leverage advanced development to provide the technical and programmatic data to identify evolving space transportation and system requirements and to evaluate new space transportation initiatives. Complementary objectives are to assimilate generic technology and advanced planning activities, and to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices. Activity is focused on three major areas--advanced transportation, advanced operations support, and satellite servicing. Concept definition and key advanced development are under way and planned in these areas to assess performance, reliability and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Included as part of the Advanced Programs Development program are definition studies of a Assured Crew Return Vehicle (ACRV) to provide assured crew return capability from the Space Station manned base and continuation of studies for a Shuttle-C concept which could provide a heavy-lift cargo capability utilizing Space Shuttle elements and infrastructure.

The Advanced Transportation Technology activity, in support of the Human Exploration Initiative, will include studies of heavy-lift launch vehicle concepts to support potential Lunar and Mars missions as well as technology for advanced liquid cryogenic propulsion system for future transportation systems. This effort builds upon NASA Shuttle-C studies as well as the joint DOD/NASA Advanced Launch System which is supporting technology development for a family of new launch vehicles aimed at significantly reducing the cost of space transportation. The Advanced Launch System (ALS) is a joint DOD/NASA program focused on this nation's next generation unmanned launch systems. In FY 1990, NASA anticipates that ALS propulsion support from DOD will be provided through reimbursable funding rather than through an appropriations transfer. In FY 1991, NASA and DOD will jointly fund development of the technology for an advanced space transportation main engine in support of ALS and heavy lift requirements.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new reusable facility for conducting space experiments and unique tethered applications in regions remote from the Shuttle orbiter. The objectives of the initial TSS mission are twofold: (1) to verify the controlled deployment, operation, and retrieval of the TSS, and (2) to quantify the interaction between the satellite/tether and space plasma in the presence of a current drawn through the tether.

The development of the OMV, initiated in 1986, will provide a space tug capability for payload delivery, retrieval, and viewing of space objects beyond the reach of the Space Shuttle. The OMV is being designed to support the Hubble Space Telescope reboost and the Advanced X-ray Astrophysics Facility (AXAF) deployment activities.

BASIS OF FY 1991 FUNDING REQUIREMENT

SPACELAB

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Development	17,000	12,000	17,200	11,400
Operations	70,600	86,900	78,400	119,300
Total	87,600	98,900	95,600	130,700

OBJECTIVES AND STATUS

The Spacelab is a versatile facility designed for installation in the cargo bay of the orbiter which affords scientists the opportunity to conduct scientific experiments in the unique environment of space. The reusable Spacelab system enhances the advancement of scientific research by serving as both an observatory and laboratory in space. Ten European nations, including nine members of the European Space Agency (ESA), have participated in this joint development program with NASA. ESA designed, developed, produced, and delivered the first Spacelab hardware consisting of: a pressurized module and unpressurized pallet segments, an igloo which is used with pallets to supply equipment, computers and services essential to the experiments, an instrument pointing subsystem (IPS), and much of the ground support equipment and software for both flight and ground operations.

NASA procured an additional set of Spacelab hardware from ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement. The associated development activities include additional hardware to complete the Spacelab carrier system, ground support equipment, hardware modifications, hardware acquisition, system recertification, and qualification and procurement of reliable and high capacity AP-101SL computers. Support software and procedures development, testing, and training activities not provided by ESA, which are required for the Spacelab, are also included in NASA's funding. Additional Spacelab hardware, including the initial lay-in of spare hardware, is being procured from European and U.S. sources.

NASA has developed two principal versions of the Spacelab Pallet System (SPS). One will support missions requiring the igloo and pallet in a mixed cargo configuration like the Astro series; the other version, the Enhanced Pallet System (EMP), will support missions that do not require use of the igloo such as the

Control Structural Interaction (CSI), the Structural Technology Experiment Platform (STEP) and the Tethered Satellite System. In addition, the development of the Hitchhiker system is nearly complete. The Marshall Space Flight Center (MSFC) version of the Hitchhiker, which was transferred to GSFC, will fly its verification flight as STP-1 (Space Test Program) in early FY 1991.

The Spacelab operations budget includes mission planning, mission integration, and flight and ground operations. This includes integration of the flight hardware and software, mission independent crew training, system operations support, payload operations control support, payload processing, logistical support and sustaining engineering.

Previous major Spacelab missions include Spacelab-1 flown in FY 1984 and Spacelab-2 and Spacelab-3 which were flown in FY 1985. Spacelab D-1 (Deutschland-1) was flown during the first quarter of FY 1986. Astro-1, originally planned for flight in FY 1986 for observation of Halley's Comet, was delayed to FY 1990 due to the Challenger accident. The initial flight of the Goddard Space Flight Center Hitchhiker (HG-1) took place in the first quarter of FY 1986.

In addition to these missions, analytical and physical integration, configuration management, and software development for future flights will be conducted. Procurement of spares for both NASA-developed hardware and for hardware developed by U. S. companies under contract with ESA will continue throughout FY 1990 and FY 1991 as will operation of the depot maintenance program for U. S.-provided and European-supplied hardware.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a decrease of $3.3 million resulting from the rephasing of contractor manpower based on the latest manifest.

BASIS OF FY 1991 ESTIMATE

The FY 1991 request reflects an increase in the scheduling and frequency of Spacelab missions which had been significantly delayed by the Challenger accident. Funding provides for the integration and payload processing of three to four major and three to four secondary missions per year. The FY 1991 development funds are required to procure additional computers and experiment hardware and to upgrade or replace obsolete hardware in order to support an accelerated and more active Spacelab traffic flow. The FY 1991 operations funds are required to support increased payload operations activities and to continue payload integration support, mission independent training, and logistics support. This support includes analytical integration, configuration management, hardware integration and software development and integration. Spacelab operations also provides for replenishment spares, the operation of the depots for both U. S. and European hardware and software, and sustaining engineering of all hardware and software. Funding is also included for the Getaway Special (GAS) program which was transferred from Shuttle Operations in FY 1989.

Included in the FY 1991 operations support of the Spacelab carrier missions is funding required for a number of major and minor missions. The NASA major missions requiring mission integration and payload processing in FY 1991 include the International Microgravity Laboratory-1 (IML-1) and the Atmospheric Laboratory for Applications and Science (Atlas-1) which are scheduled to fly in FY 1991 and the U.S. Microgravity Laboratory-1 (USML-1) mission and the Space and Life Sciences-2 (SLS-2) mission which are planned for flight in FY 1992.

In addition to NASA missions, the Spacelab program will also support three reimbursable missions: the Japanese SL-J and the U.S. DOD Starlab, which are scheduled for FY 1991 and the German D-2 which is scheduled for FY 1992.

BASIS OF FY 1991 FUNDING REQUIREMENT

UPPER STAGES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Development	3,300	400	400	--
Procurement and operations	128,300	88,200	84,200	91,300
Total	131,600	88,600	84,600	91,300

OBJECTIVES AND STATUS

Upper Stages are required to deploy payloads to orbits not attainable by the Shuttle or core stage expendable launch vehicle alone. The Inertial Upper Stage (IUS), and the commercially developed Payload Assist Modules (PAM-A, PAM-D and PAM-DII) are currently available for use. Several other upper stages are now being commercially developed, including the Transfer Orbit Stage (TOS), which will become available for use in the near future.

The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The IUS has been launched from the Shuttle, the Titan 34-D and Titan IV Expendable Launch Vehicles. Six IUS vehicles have been contracted for launch of the Tracking and Data Relay Satellite System (TDRSS) spacecraft. The first three were funded through the TDRSS contract while the remaining three are funded under this budget element. TDRS-E and -F are planned for launch on the Shuttle. TDRS-G is also planned for launch on the Shuttle but the upper stage has not as yet been placed on contract. In addition, the IUS will be used for the Ulysses launch. Two planetary missions, Magellan and Galileo, were previously launched with IUS upper stages.

A PAM is being procured as a kick stage to be used in conjunction with the IUS for the Ulysses launch. This is the only PAM in the current upper stage budget since the remaining NASA spacecraft that require PAM stages are planned for launch on Delta launch vehicles. In those cases, the PAM is procured as part of the Delta launch service and, therefore, is included in the Expendable Launch Vehicle budget.

TOS is a three-axis stabilized perigee stage that is being developed commercially by the Orbital Sciences Corporation for use with the Space Shuttle and the Titan III. It will have the capability to place 6,000 to 13,000 pounds into geosynchronous transfer orbit. A TOS/Titan III and a TOS/Shuttle upper stage are being procured for the Mars Observer and the Advanced Communications Technology Satellite (ACTS) missions respectively, to be launched in FY 1992.

The Solid Propulsion Integrity Program (SPIP) objective is to establish the necessary engineering capability for improving the success rate of U.S.-built solid rocket motors. The program has made excellent progress in determining root causes and solutions to persistent problems plaguing motor nozzles, and has initiated similar efforts to address problems and solutions for motor bondlines. The program is successfully moving the nation's industry toward solid motors that have an improved basis in science and engineering. The program results are being used in the Redesigned Solid Rocket Motor, the Advanced Solid Rocket Motor, and DOD solid motor programs.

CHANGES FROM FY 1990 BUDGET ESTIMATE

Funding for Upper Stages is reduced a net of $4.0 million, which includes adding a TOS/Shuttle upper stage for the ACTS program, consistent with Congressional direction, which was offset by rephasing of the IUS planetary upper stages and deferral of selected work packages in the SPIP program.

BASIS OF FY 1991 ESTIMATE

Operations funds in FY 1991 are required to continue progress on the IUS Upper Stages for TDRSS and Ulysses, and the TOS Upper Stages for the Mars Observer and the Advanced Communications Technology Satellite (ACTS). FY 1991 funds are also necessary to support continuation of the Solid Propulsion Integrity Program, and to initiate procurement activity for Centaur Upper Stages in support of the Comet Rendezvous Asteroid Flyby (CRAF) mission.

BASIS OF FY 1991 FUNDING REQUIREMENT

ENGINEERING AND TECHNICAL BASE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Research and test support.................	98,900	125,500	117,700	148,500
Data systems and flight support..........	18,100	17,400	17,400	18,400
Operations support.......................	32,700	34,300	33,800	34,600
Launch systems support..................	10,900	12,600	12,700	17,000
Total................................	160,600	189,800	181,600	218,500

OBJECTIVES AND STATUS

The Engineering and Technical Base (ETB) provides the program core capability required to sustain an engineering and development base for various NASA activities at the Space Flight centers. Additional center requirements above the core level are funded by the benefiting programs, such as Space Transportation Operations, Shuttle Production and Capability Development. The centers involved are the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the Stennis Space Center (SSC).

The core level of support varies from center to center due to programmatic and institutional differences. At JSC, the core level requirement is that one shift of operations be maintained in the engineering and development laboratories and the White Sands Test Facility. Safety, reliability and quality assurance areas are also supported by the ETB core. The core level for the central computer complex is established as a two-shift operation. At KSC, the core level provides for research and development of technology to enhance launch site hardware, ground processing, support services, and safety reliability and quality assurance. ETB funds at MSFC provide for multi-program support activities, including technical labs and facilities, reliability and quality assurance, computational and communications services, and at SSC for facilities operations.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The total funding for the ETB has decreased $8.2 million in FY 1990 as the result of restricting engineering manpower at JSC and MSFC to the end of FY 89 level and deferring equipment purchases at SSC and MSFC. The limits on contractor engineering manpower at JSC and MSFC will constrain the support available to new programs such as the Advanced Solid Rocket Motor (ASRM), as well as to continuing programs entering peak development such as the Space Station.

BASIS OF FY 1991 ESTIMATE

The requested funding for ETB in FY 1991 provides for an increase of support for basic research and development facilities and services at the centers to meet critical requirements for support to Shuttle, Space Station and other space transportation activities, which have expanded their requirements significantly over the past three years following the Challenger accident and the development of the Space Station. Areas that will be increased include the core capability for SRM&QA requirements, upgrading of engineering labs, engineering support services with state-of-the-art capabilities, and provision for full manpower coverage to the single shift in the engineering labs.

In research and test support, funding is required to support computational capabilities at MSFC for engineering and science projects through the use of a Class VI computer system. This capability is required for the solution of more complex main engine three-dimensional dynamics modeling problems and for complex structural analyses. At JSC, the requested funding will provide for a five-day, one-shift operation for the engineering and development laboratories, such as the Electronic Systems Test Laboratory, the Thermal Test Area, and SRM&QA activities, as well as a full up operation of a new Class VI computer system. The computer will be used to obtain numerical solutions of very large sector materials for the aerodynamics, thermodynamics, and structural mechanics analysis associated with developing and operating manned and robotic space systems. The FY 1991 estimate restores and continues the increase in engineering support at JSC and MSFC necessary to achieve the goal of a core manpower level needed to support increased program requirements with a stable workforce not affected by individual program fluctuations. The increase in FY 1991 also funds replacement of obsolete multipurpose laboratory equipment.

Data systems and flight support will continue to provide a core level of support based on a five-day, two-shift operation of the central computer complex at JSC. Any additional requirements are the responsibility of the benefiting program.

Operations support funding will continue to provide for the maintenance of multi-program research and development facilities and equipment, chemical cleaning, engineering design, technical analysis, component fabrication, and logistics support. Examples of specific services to be provided in FY 1991 include: (1) operation and maintenance of specialized electrical and cryogenic systems; (2) operation of shops to do metal refurbishing, anodizing, plating, stripping, and etching of selected items of in-house hardware; (3) engineering, installation, operation, and maintenance of closed circuit fixed and mobile television required for the support and surveillance of tests; (4) mission imaging services, including audiovisual

mission support; (5) fabrication of models, breadboards, and selected items of flight hardware; and (6) technical documentation services. In addition, FY 1991 funds will provide the basic level of collateral support at SSC for continuing main engine testing activities.

In launch systems support, funding provides for the core capability for the engineering, scientific, and technical support for research and development activities at KSC. Specifically, the funds provide for multi-program support activities, including technical labs and facilities, and other engineering support services. The FY 1991 estimate reflects the impact of an increased flight rate on KSC support including increased requirements for nondestructive testing (NDE); more calibration and repair of test equipment; increased facility maintenance, engineering and operations; increased sampling and analysis of propellants, fluids, gases, and other materials; and equipment upgrades and replacements to support NDE, sampling and analysis, and calibration/standards.

BASIS OF FY 1991 FUNDING REQUIREMENT

PAYLOAD OPERATIONS AND SUPPORT EQUIPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Payload operations......................	45,700	60,400	47,000	94,200
Payload support equipment...............	15,000	20,700	19,700	28,300
Total.................................	60,700	81,100	66,700	122,500

OBJECTIVES AND STATUS

The objectives of the Payload Operations and Support Equipment budget are to provide payload services which are required beyond the standard STS services for NASA missions, and to provide multi-mission support equipment in support of all payload operations. Payload operations provide unique hardware, analyses, and launch site support services to support NASA missions. A significant part of the total funding directly supports integration activities for the Space Station and Space Shuttle which include development of a docking system between the orbiter and the Space Station transfer tunnel. The payload support equipment budget funds the development and acquisition of multi-mission reusable ground support equipment required for a wide range of payloads. This includes test equipment required to checkout payload-to-orbiter interfaces at KSC, mixed cargo hardware such as standard cable harnesses, and displays and controls related to payload bay operations.

CHANGES FROM FY 1990 BUDGET ESTIMATE

Payload Operations funding has decreased $14.4 million from the budget estimate. This reflects decreased requirements by deleting the replacement of the Super Guppy engines, deletion of optional services for the Commercially Developed Space Facility (CDSF), and realignment of Space Station integration activities consistent with Space Station Freedom configuration and schedule. The Space Station docking system is planned as a NASA development rather than the commercial development proposed in the FY 1990 budget request because of the complexity of the Orbiter interface and safety implications. This assessment also supports managing the development as part of Payload Operations and Support rather than under the Space Station program. The docking system will be available for use with any future payloads that require docking.

BASIS OF FY 1991 ESTIMATE

Payload operations funding is required to furnish continued payload services for currently scheduled NASA launches. Major NASA payloads receiving support during this year include the Tracking and Data Relay Satellite (TDRS), Ulysses, Space Radar Laboratory (SRL), Space Life Sciences Laboratory (SLS), and the Upper Atmospheric Research Satellite (UARS). Funding is required to initiate technical integration and operations activities to assure compatibility between Shuttle capabilities and Space Station transportation requirements. A docking system for the orbiter is being developed as part of this activity. The docking system includes both active and passive docking mechanisms and Orbiter and Station bulkhead adapters. The Space Station will develop the Space Station pressurized transfer tunnel, the sliding track mechanism, and a docking mast.

Payload support equipment estimates reflect the requirement to modify and upgrade selected payload integration facilities for safer, more efficient operations. FY 1991 funding for multi-mission payload support equipment is required for development testing and delivery of payload common communication equipment (PCCE) to accommodate required payload data transmission, and initial spares provisioning for Cargo Integration Test Equipment (CITE) and PCCE. Funds for fiber optic cabling and an upgraded operational intercom system in the industrial area at KSC are included in this budget to provide increased reliability and quality of data transmission among cargo facilities. Multi-mission payload support equipment funding also includes orbiter/payload interface hardware for groups of payloads, cargo bay cabling, modified aft flight deck panels, and associated display and controls.

BASIS OF FY 1991 FUNDING REQUIREMENT

ADVANCED PROGRAMS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Advanced transportation	20,200	22,200	21,200	26,900
Advanced operations	13,900	12,000	5,800	12,300
Satellite servicing	18,600	14,500	6,600	14,000
Total	52,700	48,700	33,600	53,200

OBJECTIVES AND STATUS

The principal objectives of Advanced Program Development are to conduct definition studies and selected advanced development to support potential new development programs, system improvements and expanded capabilities for Space Transportation Systems. The definition studies include concept definitions, selected system definition and preliminary design studies, and key advanced development addressing civil requirements for increased reliability, cost effectiveness, and capability of space flight systems. Information from these studies will support decisions on the best alternatives for developing capabilities required to support future civil mission options. High leverage advanced development efforts will be conducted to reduce future program development risks and costs through the effective application of new technology. A complementary objective is to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices.

The Advanced Program Development effort is focused on three major areas--advanced transportation, advanced operations, and satellite servicing. Advanced transportation activities include systems analysis and concept definition of manned launch vehicles and transfer stages, and systems definition of crew return and cargo vehicles. For manned flight, system assessment studies continue on Shuttle evolution concepts, as well as definition of concepts for a next generation manned vehicle. NASA and DOD continue closely related and coordinated cargo vehicle studies (Shuttle-C and the Advanced Launch System) to satisfy potential mission requirements. The continuation of Shuttle-C studies is focused on a concept to provide a near-term, heavy lift capability. The Phase A'/B definition phase for the Assured Crew Return Vehicle (ACRV) will be initiated later this year in support of the Space Station Freedom. Studies in the transfer stage area will include assessment of possible upgrades to the existing Centaur and concept definition of a new, high performance cryogenic Space Transfer Vehicle to meet potential mission requirements.

Efforts in advanced operations support systems continue to address advanced operations effectiveness as the key parameter in reducing life-cycle costs for space transportation and orbital systems as well as improving reliability and safety. Innovative operations techniques and approaches are under study and being assessed for improvement of both ground and flight support systems. Advanced development emphasizes demonstration of expert and autonomous systems technologies for current and future space transportation vehicles.

The satellite servicing program includes concept definition studies, advanced hardware development, and flight experiments to improve on-orbit servicing capabilities utilizing the Shuttle and remote servicing vehicles such as the planned Orbital Maneuvering Vehicle (OMV). These efforts are focused on defining robotic and telerobotic applications, spacecraft fluid replacement, on-orbit replaceable unit exchange, rendezvous and docking sensors, and orbital servicing enhancements to satisfy payload requirements and to improve the safety of in-space operations. Transportation-related tether application studies continue to define and implement flight experiments and demonstrations including orbital altitude changes without the use of propellants, tether initiated recovery systems for returning small payloads and articles from space, and innovative transportation systems concepts for automated and manned exploration missions in and beyond Earth orbit.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a net reduction of $15.1 million. This is consistent with Congressional reductions in the Assured Crew Return Vehicle definition study and the Advanced programs base effort. These reductions were partially offset by the $10.5 million provided for continuation of the Shuttle-C studies consistent with Congressional intent.

BASIS OF FY 1991 ESTIMATE

In FY 1991, major emphasis will continue to be placed on concept definition, system definition, and advanced development for advanced transportation, advanced operations, and satellite servicing. In the advanced transportation area, studies to define the evolution of manned vehicles, including Space Shuttle improvement and concepts for the next generation manned launch system, will be continued. Funding of the Assured Crew Return Vehicle (ACRV) Phase B definition effort will be initiated in FY 1991. Definition of the Space Transfer Vehicle, assessment of Centaur upgrades, and definition of upper stage/vehicle interfaces will continue. Selected advanced development activities in materials, avionics, and cryogenic storage and transfer will be supported.

Advanced operations efforts will emphasize the identification and demonstration of technologies to improve efficiency, flexibility and reliability of current and future space transportation systems. Included in advanced operations is the selective application of expert systems, robotics, automation, and other technologies to labor-intensive and hazardous operations. Launch processing systems, mission control applications, flight planning, training, simulation and other environments will be targeted to demonstrate emerging technologies to improve ground and flight operations.

The satellite servicing area will explore effective manned and unmanned servicing concepts. Systems, tools, and techniques will be defined to refuel, repair, and retrieve satellites on a routine basis. Detailed engineering studies will continue to assess the effectiveness of future tethered platform applications.

BASIS FOR FY 1991 FUNDING REQUIREMENT

ADVANCED TRANSPORTATION TECHNOLOGY

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Advanced launch system - civil needs......	6,500	5,000	---	3,900
Advanced launch system - propulsion.......	74,900	---	---	40,000
Shuttle-C studies..........................	---	---	(10,500)*	---
Heavy lift vehicle studies................	---	---	---	10,000
Total	81,400	5,000	(10,500)	53,900

*Funding provided within Advanced Programs under Advanced Transportation.

OBJECTIVES AND STATUS

The program objective is to define and develop the technologies which will accommodate potential launch requirements of the Human Exploration Initiative (HEI), and to support the potential development of the advanced liquid cryogenic propulsion system to support advanced space transportation concepts. In FY 1990, the Shuttle-C study efforts will continue. The FY 1991 effort builds upon the NASA Shuttle-C studies and the joint DOD/NASA Advanced Launch System (ALS) program to define a heavy-lift launch concepts based on Shuttle derived and advanced technology and operational concepts which will significantly reduce Earth-to-orbit transportation costs.

As specified in the ALS management plan, NASA has the lead for liquid engine systems and the advanced development program, including propulsion, propulsion related and non-propulsion tasks. With the current emphasis on the President's Human Exploration Initiative and the expected role of heavy-lift Earth-to-orbit transportation, NASA's contribution to the advanced development of the ALS program is increased. In concert with DOD funding, NASA funding will maintain critical activities and milestones for the propulsion advanced development activity. The propulsion advanced development program focuses on demonstrating the performance and operational capabilities of critical propulsion system components. This has been an integral element of the joint program and through FY 1990, totally funded within the DOD budget.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The funding for efforts in support of unique civil requirements was deleted in the FY 1990 appropriation legislation. Total funding for the ALS program, including the NASA managed elements, is included in the DOD budget request. While final funding levels have not been determined for FY 1990, NASA's ALS propulsion advanced development effort will be provided through reimbursable funding rather than appropriation transfers, although at a reduced level from that previously planned.

BASIS OF FY 1991 ESTIMATE

The ALS civil needs activity would be reinstated in FY 1991. These study efforts are required to insure that civil unique requirements in the joint NASA/DOD ALS program are defined and incorporated into the joint program planning. These efforts are particularly critical in FY 1991 as the ALS program evolves and the Human Exploration program is initiated.

The potential propulsion technology requirements for a tanker to move large quantities of cryogenic propellants (liquid hydrogen and oxygen) and a large volume cargo carrier will be addressed. The technical impact of these potential requirements on launch vehicle design and operations (launch operations, aerodynamic, launch static and dynamic loads, space operations, and long-term space storage etc.) will be assessed. Both Shuttle derivative and the Advanced Launch System vehicle concepts will be considered. This program activity builds on the Shuttle-C studies and the NASA/DOD Advanced Launch System (ALS) liquid engine system studies and supporting advanced development efforts.

The liquid hydrogen/liquid oxygen (LH2/LOX) engine element of the DOD/NASA Advanced Launch System program would be augmented to insure maturation of the system concepts and supporting technology to enable future development missions. Utilizing funding from both DOD and NASA, the liquid engine program will demonstrate critical turbomachinery, combustor and diagnostics technology on the component tests stands currently being constructed. Because the ALS management plan assigned lead responsibility for the liquid engine element to NASA, the existing program will be continued without significant interruption, and the basic objectives of the ALS propulsion advanced development effort will remain unchanged.

BASIS FOR FY 1991 FUNDING REQUIREMENT

TETHERED SATELLITE SYSTEM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Tethered satellite system................	26,400	19,900	24,000	17,900

OBJECTIVES AND STATUS

The development of a Tethered Satellite System (TSS) will provide a new reusable space facility for conducting space experiments at distances up to 100 kilometers from the Shuttle orbiter while being held in a fixed position relative to the orbiter. A number of significant scientific and engineering objectives can be uniquely undertaken with a TSS facility such as the observation of important atmospheric processes occurring within the lower thermosphere, new observations of crustal geomagnetic phenomena, and entirely new electrodynamic experiments interacting with the space plasma. This is being undertaken as a cooperative development program with the Italian government.

The United States is responsible for overall program management, overall systems engineering and integration, Orbiter integration, ground and flight operations, development of the deployment mechanism and provision of the non-European instruments (OSSA funded). The U. S. effort was initiated in 1984. The Italians are responsible for the design and development of the satellite and the European instruments being flown on the joint missions. They initiated their development efforts in 1984.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate incorporates an increase of $4.1 million for necessary design changes to the mechanisms used to provide control during deployment and retrieval, and systems and experiments integration effort.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding will complete the TSS flight planning and integration activities and accomplish flight operations activities. Integration of the Italian-provided satellite and the deployer-mounted science instruments is now planned to start at KSC in mid-FY 1990, in preparation for the planned engineering verification flight in mid-FY 1991.

BASIS OF FY 1991 FUNDING REQUIREMENT

ORBITAL MANEUVERING VEHICLE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Orbital maneuvering vehicle..............	73,000	107,000	76,281	85,400

OBJECTIVES AND STATUS

The reusable Orbital Maneuvering Vehicle (OMV) will provide a new STS capability for conducting orbital operations with spacecraft and payloads beyond the practical operational accessibility limits of the baseline Shuttle. Using remote man-in-the-loop control for proximity operations and docking, the OMV is being designed to operate as far as 350 nautical miles altitude above the orbiter. The OMV will provide delivery, maneuvering, and retrieval of satellite payloads to and from altitudes or inclinations beyond the existing STS capability; reboost of satellites to original operational altitudes or higher; and maneuvering and viewing of payloads at different orbital altitudes and inclinations. The OMV is being designed with the capability to accommodate add-on future "mission kits" needed for space basing and support of more advanced missions such as the servicing of satellites and platforms and the retrieval of space debris representing an orbital hazard to all future space missions. TRW was competitively selected and is now under contract to develop the OMV. The preliminary design review was held in 1988.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a $30.7 million decrease consistent with the rebaselining of the vehicle's capabilities. The rebaselining decision was driven both by program re-estimates which would have reduced reserves to an unacceptably low level and by a reassessment of the initial launch requirement. The project requirements and capabilities have now been directed to supporting the Hubble Space Telescope reboost requirement and the Advanced X-ray Astrophysics Facility (AXAF). Planned capabilities not necessary to meet these requirements have been deleted as part of the rebaselining effort. However, the ability to restore individual capabilities will be maintained to satisfy future mission requirements.

BASIS OF FY 1991 ESTIMATE

The funds provided in FY 1991 will be used to complete the design of the rebaselined vehicle and provide the engineering documentation and support for conducting the critical design review.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1991 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR SPACE SCIENCE AND APPLICATIONS

	Budget Plan				
		1990		1991	
	1989 Actual	Budget Estimate	Current Estimate	Budget Estimate	Page Number
		(Thousands of Dollars)			
Physics and astronomy	737,400	894,500	861,378	985,000	RD 3-1
Life sciences	79,100	124,200	106,278	163,000	RD 4-1
Planetary exploration	416,600	396,900	391,686	485,200	RD 5-1
Earth science	403,400	434,300	439,299	661,500	RD 6-1
Materials processing in space	75,600	92,700	99,015	97,300	RD 7-1
Communications	92,200	18,600	77,975	52,800	RD 8-1
Information systems	19,900	34,100	28,217	36,800	RD 9-1
Total	1,824,200	1,995,300	2,003,848	2,481,600	

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PHYSICS AND ASTRONOMY

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Hubble space telescope development.......	104,900	67,000	81,800	--	RD 3-7
Gamma ray observatory development........	50,900	26,700	35,100	--	RD 3-9
Global geospace science..................	64,400	112,300	67,200	98,500	RD 3-11
Advanced x-ray astrophysics facility development (AXAF)....................	16,000	44,000	44,000	113,000	RD 3-13
Payload and instrument development.......	70,500	71,400	90,655	97,200	RD 3-15
Shuttle/Spacelab payload mission management and integration.............	67,700	86,100	81,248	89,100	RD 3-17
Space station integrated planning and attached payloads......................	8,000	23,000	4,975	15,000	RD 3-19
Explorer development.....................	82,100	93,200	91,800	100,800	RD 3-21
Mission operations and data analysis.............................	142,400	204,800	202,400	293,900	RD 3-24
Research and analysis....................	85,100	112,500	109,500	122,500	RD 3-26
Suborbital program.......................	45,400	53,500	52,700	55,000	RD 3-28
Total..............................	737,400	894,500	861,378	985,000	

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Distribution of Program Amount by Installation				
Johnson Space Center.....................	14,570	16,917	15,747	17,210
Kennedy Space Center.....................	7,930	11,647	10,330	10,344
Marshall Space Flight Center.............	307,942	189,002	215,604	272,374
Goddard Space Flight Center..............	295,058	543,084	512,243	559,240
Jet Propulsion Laboratory................	22,500	17,988	16,037	30,777
Ames Research Center.....................	20,000	25,886	20,246	9,305
Langley Research Center..................	150	--	--	--
Lewis Research Center....................	--	500	--	450
Headquarters.............................	69,250	89,476	71,171	85,300
Total..................................	737,400	894,500	861,378	985,000

OBJECTIVES AND JUSTIFICATION

The objectives of the Physics and Astronomy program are to increase our understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. Objects studied by the astrophysics program include distant galaxies and galactic clusters, as well as stars and other structures in nearby galaxies and the interstellar medium in our galaxy. Unusual and exotic phenomena -- such as quasars, neutron stars, pulsars and black holes -- are of particular interest to the astrophysics program, and are the target of many ground-based and space-based research programs.

In the Space Physics program, intensive study of our own Sun, with its multitude of time-varying phenomena, provides key answers to a vast range of questions requiring comprehensive research into solar-terrestrial processes and the physics and coupling between the solar wind, magnetosphere, ionosphere, and atmosphere.

The objectives of the Physics and Astronomy program are accomplished with a mixture of large, complex free-flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights and suborbital missions. In the future, Space Station Freedom will act as a platform for attached payloads. Space-based research allows observations in the infrared and the ultraviolet wavelengths which are unobtainable on the ground due to the obscuring effects of the atmosphere. Also, observations in the visible light region are vastly improved when conducted above the atmosphere. The entire program rests on a solid basis of supporting research and technology, data analysis, and theory.

Research teams involved in this program are located at universities, industrial laboratories, NASA field centers, and other government laboratories. The scientific information obtained and the technology developed in this program are made available to the scientific communities and the general public for application to the advancement of scientific knowledge, education and technology.

The Physics and Astronomy missions undertaken to date have been extraordinarily successful. Recently, these include the High Energy Astronomical Observatories (HEAO, 1977-1979), the International Ultraviolet Explorer (IUE, 1978), the Solar Maximum Mission (SMM, 1980) the Active Magnetospheric Particle Trace Explorer (AMPTE, 1984), the Dynamics Explorer (DE, 1981), the Interplanetary Monitoring Platform (IMP-8,

1972), International Sun-Earth Explorers (ISEE 1 & 2 and ICE, 1977-78), and the Infrared Astronomy Satellite (IRAS, 1983) and San Marco-D (1988), and the recently-launched Cosmic Background Explorer (COBE 1989). The IUE, IMP, DE, ICE and COBE are still operating, and new scientific results are continually emerging from these, as well as from the high quality data sets archived from the HEAO's, ISEE 1 & 2, SMM, AMPTE, and IRAS missions.

The Hubble Space Telescope (HST), scheduled to be launched by the Space Shuttle during FY 1990, will provide an international spaceborne astronomical observatory capable of measuring objects appreciably fainter and more distant than those accessible from the ground, since it will be above the turbulent and absorbent atmosphere. This telescope will be able to resolve spatial features by a factor of ten better than ground-based optical telescopes, and will be able to observe approximately 100 times the volume of the universe that we can currently see. This increased capability will allow us to address basic questions concerning the origin, evolution, and disposition of galaxies, quasars, clusters, and stars, thus allowing us to significantly increase our understanding of both the early and present universe--its beginning and end.

The Gamma Ray Observatory (GRO) mission will also be launched by the Space Shuttle in FY 1990. This mission will measure gamma rays, which are produced by the most energetic and exotic fundamental physical processes occurring in nature. Instruments on this mission will provide unique information on phenomena occurring in quasars, active galaxies, black holes, neutron stars, supernova, and the nature of the mysterious cosmic gamma-ray bursts.

The Global Geospace Science (GGS) program is a complementary science mission to the Collaborative Solar-Terrestrial Research (COSTR) project and establishes the U.S. as a leader in solar-terrestrial physics research. These projects, collectively referred to as the International Solar-Terrestrial Physics (ISTP) program, are being conducted in cooperation with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). GGS will make the first coordinated geospace measurements in the key plasma source and storage regions, with emphasis on the cause-effect relations of energy flow. Together with COSTR, GGS represents research of the highest scientific merit.

The Advanced X-ray Astrophysics Facility (AXAF) was approved as a FY 1989 new start for the x-ray telescope assembly and high resolution mirror assembly. The start of instrument development is planned for FY 1990, and start of spacecraft development is planned for FY 1992. AXAF will be a major national observatory for x-ray astronomy. The 1.2 meter-class grazing incidence telescope will provide a factor of 100 increase in sensitivity, a factor of 10 increase in angular resolution and double the energy coverage provided by the Einstein observatory (HEAO-2). It will provide new observations and insights in studies of stellar structure and evolution, large-scale galactic phenomena, active galaxies, clusters of galaxies and cosmology. It will restore U.S. leadership in a field pioneered by the U.S. astronomers.

The Astrophysics program continues its involvement in the Shuttle/Spacelab program with Astro-1, a set of ultraviolet and soft x-ray telescopes and spectrometers, scheduled for launch in 1990. Astro-1 will investigate the interstellar medium by following up on discoveries made with the IUE. Mission management activities will continue with increasing emphasis on major life sciences and microgravity research missions such as the series of Spacelab-Life Sciences (SLS), International Microgravity Laboratory (IML) and the United States Microgravity (USML) missions.

The Physics and Astronomy Explorers have been extremely successful. The IUE, a U.S./ESA endeavor, has recently shown that our galaxy has a halo of gas with a temperature of over a million degrees, while the IRAS, a joint U.S./U.K./Netherlands project, detected and has enabled a cataloging of over 300,000 infrared sources and has shown star formation in other galaxies to be more prevalent than previously thought. IRAS also demonstrated that at least one quasar has its dominant energy release in the infrared spectral region. Since IRAS completed operations in late 1983, these discoveries have come from analysis of archival data, with many more such results expected. ICE, which was designed to provide solar wind data, was redirected in 1985 for the first successful encounter with a comet when it passed through the tail of Comet Giacobini-Zinner, and made Halley's Comet observations in 1986. After successfully taking equatorial measurements of the ionosphere, the spacecraft reentered the Earth's atmosphere in December 1988.

The Cosmic Background Explorer (COBE), a major Explorer mission, was successfully launched in November 1989. Another major Explorer mission currently under development is the Extreme Ultraviolet Explorer (EUVE), scheduled for launch in 1992. A third mission, the X-ray Timing Explorer (XTE), is about to begin development. In addition, a U.S. instrument has been developed for inclusion on the Roentgen Satellite (ROSAT), being built by the Federal Republic of Germany and scheduled for launch in FY 1990. A Cosmic Ray Isotope Experiment (CRIE) has been developed along with a DOD experiment, for flight aboard the Combined Release and Radiation Effects Satellite (CRRES), a collaborative mission with the DOD and is also scheduled for launch in 1990. We are developing an instrument for flight on the Japanese Solar-A mission (previously called the High Energy Solar Physics Mission, HESP). Solar-A will be launched in FY 1991 to study the Sun during the upcoming solar maximum. Finally, the Explorer program supports U.S. participation in the Japanese Astro-D Spectroscopic X-ray Observatory Mission, to be launched in 1993.

Advanced Technological Development activities will continue on the Orbiting Solar Laboratory (OSL), a platform for studies of solar magnetic structures, processes and surface atmosphere, toward a potential new start in the early 1990s. Definition studies of the advanced technology necessary for a Space Infrared Telescope Facility (SIRTF) will continue. SIRTF is intended to measure phenomena associated with the beginning of an evolutionary cycle. This includes cosmic dust, cool interstellar material, star formation, and proto-planetary nebulae in both our galaxy and others.

Payload and instrument development activities provide the data necessary to conduct basic research projects and to provide correlative and development feasibility information for major free-flying spacecraft. Instrument development activities include Shuttle payloads such as the Tethered Satellite System (TSS). Also included are Space Plasma Physics flight of opportunity instruments such as those for the Japanese Geotail spacecraft and the European Solar and Heliospheric Observatory (SOHO) and Cluster spacecraft under the COSTR program. The COSTR instrumentation provides the U.S. complement for the European Solar Terrestrial Science Programme (STSP).

The first nearby Supernova, since the invention of the telescope, appeared in the southern skies in 1987. Since that time, the Physics and Astronomy program mounted a broad campaign of observations using the Deep Space Network, aircraft, balloons, rockets, and existing spacecraft to take advantage of this unique scientific opportunity.

During the Shuttle recovery period, suborbital observation from balloons, sounding rockets, and high-flying aircraft took on increased significance. This enhanced effort will provide observations and instrument development opportunities for research groups. Furthermore, increased emphasis will also continue in the Research and Analysis (R&A) and the Mission Operations and Data Analysis (MO&DA) areas in order to maintain a vital research base in Physics and Astronomy.

BASIS OF FY 1991 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spacecraft	91,900	59,000	73,000	--
Experiments	13,000	8,000	8,800	--
Total	104,900	67,000	81,800	--
Mission operations and data analysis	(98,300)	(134,400)	(132,400)	(191,900)
Space transportation system operations	(66,400)	(--)	(20,500)	(--)

OBJECTIVES AND STATUS

The Hubble Space Telescope (HST) will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe. The HST will operate in space above the atmospheric veil surrounding the Earth, increasing dramatically the volume of space accessible for observations. With its significant improvements in resolution and precision in light sensitivity and in wavelength coverage, the HST will permit scientists to conduct investigations that could never be carried out with ground-based observatories limited by the obscuring and distorting effects of the Earth's atmosphere.

The HST will enhance the ability of astronomers to study radiation in the visible and ultraviolet regions of the spectrum. It will be more sensitive than ground-based telescopes and will allow the objects under study to be recorded in greater detail. It will make possible unique observations of objects so remote that the light will have taken many billions of years to reach the Earth. As a result, we will be able to look farther into the distant past of our universe than ever before. The HST will also contribute significantly to the study of the early state of stars and the formation of solar systems, as well as the observation of such highly-evolved objects as supernova remnants and white dwarf stars. With the HST, we may be able to determine the nature of quasars and the processes by which they emit such enormous amounts of energy; it may also be possible to determine whether some nearby stars have planetary systems.

The HST is scheduled to be delivered into orbit by the Space Shuttle in March 1990. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The HST is designed for on-orbit maintenance and repair.

During FY 1989, the HST completed testing and rework at the Lockheed Missiles and Space Company in Sunnyvale, California and was then prepared for transport to the Kennedy Space Center in a modified C-5A transport plane. Activity in FY 1989 and FY 1990 reflects a launch delay from December 1989 to March 1990.

Planning for FY 1990 includes the actual shipment of the HST to the Kennedy Space Center (which was completed successfully October 1989) and preparations and processing for the March 1990 launch. Any launch delay beyond this currently-manifested date would require additional funding to be made available. Development funding supports prelaunch preparations and orbital checkout activities through launch-plus-thirty days as well as the evaluated final award fee payments. Any launch delay beyond this currently-manifested date would require additional funding to be made available.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects the necessary addition of funds because of the launch delay to March 1990.

BASIS OF FY 1991 FUNDING REQUIREMENT

GAMMA RAY OBSERVATORY DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Spacecraft	42,300	21,500	30,300	--
Experiments and ground operations	8,600	5,200	4,800	--
Total	50,900	26,700	35,100	--
Mission operations and data analysis	(1,000)	(11,000)	(8,100)	(29,000)
Space transportation system operations	(52,600)	(55,500)	(55,000)	--

OBJECTIVES AND STATUS

The Gamma Ray Observatory (GRO) will study the highest energy electromagnetic radiation emitted from sources in the cosmos. This spectral region represents one of the last frontiers in astronomy to be studied at high sensitivity. Because of their extreme energy, gamma-rays are produced by the most energetic and intriguing phenomena occurring in the universe: phenomena occurring in the central energy source region of quasars, in supernovae, near black holes, and on the surface of neutron stars. Gamma-rays provide the unique direct signature of all nuclear processes which occur in astrophysics: the synthesis of elements, cosmic rays interacting in the interstellar medium, and transformations involving the fundamental particles of physics. GRO will provide new information on phenomena ranging from the enigmatic, and yet unidentified, cosmic gamma-ray bursts, to the diffuse gamma-ray sky background, whose origin must have cosmological significance.

The GRO science and instrumentation rests on a foundation of exploratory investigations and developments from previous spacecraft, such as the Small Astronomy Satellite-2 (SAS-2, 1972), the High Energy Astronomical Observatories (HEAO's 1 and 3, 1977 and 1979), and the European COS-B (1975). A community of astronomers and physicists has built up both the data analysis experience and developed the theoretical concepts to complete the infrastructure required for a successful space mission. Participation in the GRO mission includes the university science community as well as government and industry. International involvement, with a complete Principal Investigator team based in Europe, is extensive.

Due to the low flux of cosmic gamma-rays, their penetrating nature, and the high background produced by cosmic-ray interactions, detailed observations require large instruments to be flown in space for extended periods of time. The four complementary instruments selected for the GRO represent a quantum jump in sensitivity, spectral range, and spectral, spatial, and temporal resolution over any previous missions or instruments in these energy ranges. GRO, scheduled for launch on the Space Shuttle in 1990, is designed to be pointed at fixed directions in space for hours or weeks to obtain the long exposures required.

In FY 1989, all instruments were delivered to TRW Inc. in El Segundo, California and integrated with the GRO spacecraft. Functional and environmental testing was completed ahead of schedule.

In FY 1990, GRO will be transported by aircraft to the Kennedy Space Center. Following processing and other prelaunch preparations, GRO is scheduled to be launched June 1990. On-orbit checkout and payment of award fee will complete GRO development activities.

CHANGES FROM FY 1990 BUDGET ESTIMATE

FY 1990 funding for GRO development is increased by $8.4 million and GRO Mission Operations and Data Analysis (MO&DA) is reduced by $2.9 million to reflect the launch slip from April to June as well as the general Congressional reduction and the impact of sequestration.

BASIS OF FY 1991 FUNDING REQUIREMENT

GLOBAL GEOSPACE SCIENCE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Global geospace science..................	64,400	112,300	67,200	98,500
Space transportation systems operations..	(--)	(10,000)	(18,300)	(60,600)

OBJECTIVES AND STATUS

Global Geospace Science (GGS) will be part of the United States' contribution to the International Solar Terrestrial Physics (ISTP) program. This program is an international, multi-spacecraft, collaborative science mission designed to provide the measurements necessary for a new and comprehensive understanding of the interaction between the Sun and the Earth.

GGS is a complementary science mission to the Collaborative Solar Terrestrial Research (COSTR) program which provides instruments and launch support to gain science return in a cooperative effort with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). The scientific value of this effort will be greatly enhanced by the addition of the two GGS spacecraft. The combined program will include five spacecraft missions: two U.S. spacecraft, Wind and Polar; two ESA spacecraft, SOHO and Cluster; and one ISAS spacecraft, Geotail.

The GGS mission will measure and model the effects of the Sun on the Earth's space system to enhance our understanding of the processes and flow of energy and matter in the solar energy chain from outer geospace to atmospheric deposition. GGS will also enhance our ability to assess the importance of variations in atmospheric energy deposition from the geospace system to the terrestrial environment. GGS consists of two fully-instrumented U.S. spacecraft, Wind and Polar, making simultaneous measurements in key geospace regions. Instruments and theory investigations were selected through an Announcement of Opportunity to U.S. and foreign investigators. GGS provides the first coordinated geospace measurements in key plasma source and storage regions, multi-spectral global auroral imaging, and multi-point study of magnetospheric response to solar wind. Wind and Polar are planned for launch in FY 1993.

Essentially all commitments by the foreign governments are in place and their development activities have commenced. Spacecraft contract award was completed in FY 1989, as was final confirmation and initiation of instrument development activity. GGS will allow the United States to become a full partner in the ISTP program, reinforcing our commitments to international cooperation and maintaining a leadership role in solar-terrestrial physics.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The GGS program has recently revised its estimates of the funding levels needed to support the instrument and spacecraft development contracts for the Wind and Polar missions as a result of negotiations leading to the spacecraft contract award. This revision allows the program to defer $43.5 million of funding requirements to later fiscal years without impact to scheduled launch dates. $5.5 million of this total will be transferred to the Missions Operations and Data Analysis (MO&DA) program to support guest observations and archival data analysis for missions that are acting as scientific precursors for the GGS program. The remaining $38.0 million is reallocated to other high priority Physics and Astronomy programs, including HST and GRO to fund the launch delays. The program has further been reduced by $1.6 million due to the general Congressional reduction.

BASIS OF FY 1991 ESTIMATE

FY 1991 funds are required to continue development of GGS spacecraft, instruments and ground system. Funding will allow continuation of these development efforts in order to take advantage of simultaneous measurements provided by the COSTR program and other solar-terrestrial research efforts. Integration of both the Wind and Polar spacecraft will occur during FY 1991. Continued development on the 19 Wind and Polar instruments will lead to the Wind instruments' deliveries in late FY 1991, at which point instrument integration will occur.

BASIS OF FY 1991 FUNDING REQUIREMENT

ADVANCED X-RAY ASTROPHYSICS FACILITY DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Mirror development	16,000	35,000	40,900	94,500
Experiments	--	9,000	3,100	18,500
Total	16,000	44,000	44,000	113,000
Mission operations and data analysis	(--)	(1,000)	(1,000)	(4,000)

OBJECTIVES AND STATUS

The Advanced X-ray Astrophysics Facility (AXAF) is the next major advance in x-ray astronomy and is the third of the four "Great Observatories". AXAF will provide new observations and insights into studies of stellar structures and evolution, large-scale galactic phenomena, active galaxies, clusters of galaxies, and cosmology. The 1.2 meter grazing incidence telescope will provide a factor of 100 increase in sensitivity, a factor of ten increase in angular resolution, double the energy coverage which was provided by the Einstein Observatory (HEAO-2), and will address fundamental questions of modern astrophysics. Timely development of the AXAF program is required in order to fly in concert with the Hubble Space Telescope, which will observe the universe in visible and ultraviolet radiation, and the Gamma Ray Observatory, which will conduct observations in the gamma ray spectrum. The scientific return of these Great Observatories will be enhanced enormously if flown together to observe the whole range of phenomena in the cosmos, from the most tranquil to the most violent, and provide a complete physical picture of the universe's most engimatic objects.

AXAF will be a long-lived observatory designed for on-orbit instrument replacement and servicing. With the Shuttle, and Space Station Freedom, the U.S. will have the unique capability to maintain this telescope in orbit.

In FY 1989, AXAF development activities commenced on the High Resolution Mirror Assembly/X-ray Telescope Assembly (HRMA/XTA), with a particular focus on development of the flight mirrors at Perkin-Elmer in Danbury, Connecticut. Per Congressional agreement, AXAF instrument and observatory definition activities were funded under Research and Analysis.

In FY 1990, development continues on the largest and most challenging set of parabolic/hyperbolic mirrors (P-1/H-1). Science instrument development is scheduled to begin during FY 1990; the most challenging instrument, the X-ray Spectrometer (XRS), must achieve five key milestones by January 1990 in order to be included in the flight payload.

CHANGES FROM FY 1990 BUDGET ESTIMATE

Although total program funding remains unchanged, mirror development funding has been augmented in order to maintain the technology demonstration milestone scheduled for the summer of 1991.

BASIS OF FY 1991 ESTIMATE

In FY 1991, mirror development activities will lead to performance verification at Perkin-Elmer and by x-ray test at the X-ray Calibration Facility at the Marshall Space Flight Center. Spacecraft definition activities will begin preparations for the AXAF Program Systems Requirements Review scheduled for mid-FY 1992.

BASIS OF FY 1991 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Collaborative solar terrestrial research.	32,700	54,800	53,900	61,800
Tether satellite systems.................	7,700	6,200	6,800	3,400
Shuttle test of relativity experiment....	17,900	--	21,655	26,000
Astrophysics payloads....................	9,600	7,200	5,900	3,800
Space physics payloads...................	2,600	3,200	2,400	2,200
Total..................................	70,500	71,400	90,655	97,200

OBJECTIVES AND STATUS

Instrument development activities support a wide range of instrumentation - from early test, checkout and design of instruments for long-duration free-flying missions to international flights of opportunity. The Collaborative Solar Terrestrial Research Program (COSTR) will provide state-of-the-art instrumentation for flight opportunities on international spacecraft and various U.S. spacecraft of opportunity. Emphasis is on developing scientific instruments conceived through the Space Physics Research and Analysis and Sounding Rocket programs. Instruments to be developed in the near term will provide a U.S. contribution to an international thrust in space physics research in the 1989-1995 timeframe, principally, the European Solar Terrestrial Science Programme (STSP) and the Japanese Geotail Mission.

The Tethered Satellite System (TSS), scheduled for launch in FY 1991, will provide a facility for conducting experiments weighing 500 kg or less from distances of 100 km above or below the Space Shuttle. The objective of the initial TSS mission (TSS-1) is to verify the controlled deployment, retrieval and on-station stabilization of a satellite tethered from the orbiter, and to carry out an electrodynamics experiment using a conducting tether extended 20 km above the orbiter. TSS-1 is an international cooperative project with the Italian government. The U.S. is responsible for overall project management, system integration, developing the tether deployment and retrieval system, developing and integrating U.S.-provided instruments, and flight on the Space Transportation System (STS). Italy is developing the satellite and is responsible for development and integration of Italian-provided instruments.

Astrophysics and space physics payloads include a number of instruments designed for flight on the STS and ELV's. Emphasis will be on instrument development for study of the complex relationships of solar irradiance and the near-Earth plasma environment (Atmospheric Laboratory for Applications and Science - ATLAS Spacelab mission), scheduled for a 1991 flight, as well as for study of the ultraviolet and x-ray universe (Astro-1 and Diffuse X-ray Spectrometer (DXS)).

The Shuttle test flight of the Gravity Probe-B instrument involves the development of a multigyroscope experimentation package to fly as an attached payload on the Shuttle in 1994, as an integral part of the study of relativity.

FY 1990 activities also include definition, design and initial development for several instruments planned for international flights of opportunity. The X-ray Multimirror Mission (XMM) with the European Space Agency will incorporate two NASA x-ray instruments aboard the spacecraft scheduled for launch in 1998. The Spectrum X Gamma (SXG) mission is a cooperative effort with the U.S.S.R. which will include two NASA instruments (an all-sky monitor and polarimeter) on its planned flight in 1993. A 1992 Spacelab flight will include the German Astrospas-Orpheus, in which NASA is developing two instruments.

CHANGES FROM 1990 BUDGET ESTIMATE

Tether payloads has increased in order to accommodate cost growth on the prime contract. COSTR has been reduced resulting from the general Congressional reduction. The Shuttle test flight of the Gravity Probe-B instrument was restored in the FY 1990 appropriation at $22 million. The decrease of $345K in FY 1990 is due to the general Congressional reduction as well as the impact of sequestration. The reduction in Astrophysics and Space Physics payloads reflects the impact of the legislated general reduction as well as the cancellation of the Astro-2 mission in response to the reduced availability due to the sequestration.

BASIS OF FY 1991 ESTIMATE

In FY 1991, the COSTR program will continue development of U.S. provided instruments for the ISAS/NASA Geotail mission which will explore the Earth's magnetosphere and deep geotail region. NASA will also be developing U.S. provided instruments and mission support equipment for the ESA/NASA joint Cluster and SOHO missions, which will provide unique capabilities for measuring solar oscillations and solar corona. Funding is also required to continue development of U.S. provided instruments and for core equipment development and integration on TSS-1. Funding for the Shuttle test flight of the Gravity Probe-B instrument will continue. Funding will support data analysis from the Astro-1 mission, as well as development of instruments for the ATLAS and DXS missions. Funding will also be applied to the U.S.-provided instruments on the international/cooperative efforts consistent with current agreements.

BASIS OF FY 1991 FUNDING REQUIREMENT

SHUTTLE/SPACELAB/PAYLOAD MISSION MANAGEMENT AND INTEGRATION

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Shuttle/Spacelab payload mission management and integration.............	67,700	86,100	81,248	89,100

OBJECTIVES AND STATUS

The primary objective of the Spacelab Payload Mission Management program is to manage the mission planning, integration, and execution of all NASA Spacelab and attached Shuttle payloads. This includes system management and engineering development of flight support equipment and software; development of certain interface hardware; payload specialist training and support; integration of the science payloads with the Spacelab system; payload flight operations; and data dissemination to experimenters.

Mission management activities are continuing for Physics and Astronomy missions including the ASTRO-1 and DXS missions. ASTRO-1 is scheduled for flight in 1990; DXS is currently planned for flight in 1992. Mission management activities are ongoing for on several other space science and applications missions, such as the Atmospheric Laboratory for Applications and Science (ATLAS). The first of this series is planned for flight in 1991. The mission will incorporate a large number of instruments designed to study the complex relationships of solar irradiance, atmospheric composition and changes, and the near-Earth plasma environment. Other missions include flight of an imaging radar in the early 1990's; a series of Spacelab Life Sciences missions (SLS), the first scheduled for launch in August 1990; a joint microgravity mission with the Japanese (SL-J); a series of cooperative International Microgravity Laboratories (IML's); a series of U.S. Microgravity Payloads (USMP's) and U.S. Microgravity Laboratories (USML's); and flight of the Canadian WISP instrument as part of an OMV demonstration mission. Mission management activities also support other (non-OSSA) payloads; for example, the Lidar In-space Technology Experiment (LITE) will demonstrate technology and measurement techniques with high potential for use in studies of Earth's atmosphere. Several middeck experiments are also supported.

CHANGES FROM FY 1990 BUDGET ESTIMATE

As a result of the general Congressional reduction and the impact of sequestration, the Astro-2 mission has been cancelled, which accounts for the decrease.

BASIS OF FY 1991 ESTIMATE

Mission management activities will escalate in FY 1991 as Spacelab missions become more frequent. Funding will support all currently manifested missions.

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BASIS OF FY 1991 FUNDING REQUIREMENT

SPACE STATION INTEGRATION PLANNING AND ATTACHED PAYLOADS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space station integration planning and attached payload definition............	8,000	23,000	4,975	15,000

OBJECTIVES AND STATUS

The primary aim of the space station integration planning and attached payload definition program is to perform the necessary planning and definition of payloads for the Office of Space Science and Applications use of Space Station Freedom (SSF). This includes the initial definition of the attached payloads, selected in FY 1989 through a competitive Announcement of Opportunity for early deployment on the Space Station. The program also involves definition of integration and operations requirements to guide the planned development of Space Station and science support capabilities.

In FY 1990, the program will provide the Space Station Freedom designers with appropriate levels of information concerning science requirements. Studies continue to define the end-to-end science operations requirement for the Space Station era (i.e., the cycle from identification of an experiment, through operations to dissemination, analysis and archiving of data). Studies also continue to determine the best use of Space Station resources (such as power, crew time, volume, data handling capabilities) for science requirements.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The change from the FY 1990 Budget Estimate is due to the Congressionally-directed decrease of $13.7 million, as well as the general Congressional reduction and the impact of sequestration. This reduction will necessitate a deferral of preliminary science integration and utilization studies, but will still support the completion of initial payloads in accordance with the current Space Station schedule requirements.

BASIS OF FY 1991 ESTIMATE

In FY 1991, the budget estimate will continue to compile a science base for the Space Station--SSF resources requirements, unique user requirements, etc. Definition will continue on the attached payloads selected for early flight on SSF. Science utilization management planning activities for the OSSA payloads, such as operations support and accommodations and requirements analysis will also proceed. Definition of the Space Station Information System will continue.

BASIS OF FY 1991 FUNDING REQUIREMENT

EXPLORER DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Cosmic background explorer	16,600	--	3,100	--
Extreme ultraviolet explorer	14,000	15,700	14,500	10,900
Explorer platform	26,400	30,100	31,800	16,500
X-ray timing explorer	--	10,600	9,600	23,900
Roentgen satellite experiments	3,700	1,700	1,700	--
Combined release and radiation effects satellite experiments	2,200	2,200	2,200	--
Solar-A	6,700	3,200	6,600	3,100
Small explorers	3,500	14,800	14,600	29,100
Other explorers	9,000	14,900	7,700	17,300
Total	82,100	93,200	91,800	100,800

OBJECTIVES AND STATUS

Investigations selected for these projects are usually of an exploratory or survey nature, or have specific objectives not requiring the capabilities of a major observatory. Past Explorers have discovered radiation trapped within the Earth's magnetic field, investigated the solar wind and its interaction with the Earth, studied upper atmosphere dynamics and chemistry, mapped our galaxy in radio waves and gamma-rays, and determined properties of the interstellar medium through ultraviolet observations. Recent Explorers have performed active plasma experiments on the magnetosphere, made in situ measurements of the comet Giacobini-Zinner, and completed the first high sensitivity, all-sky survey in the infrared, discovering over 300,000 sources.

The Cosmic Background Explorer (COBE) was launched in November 1989 on a Delta Expendable Launch Vehicle (ELV) and is currently studying the properties of the cosmic microwave background, This is important for understanding the early universe and cosmology. COBE will carry out a definitive, all-sky exploration of the infrared background radiation of the universe between the wavelengths of one micrometer and 9.6 millimeters.

Explorers under development will survey the sky in the extreme ultraviolet for the first time, and measure time-variable phenomena in x-ray sources. The Explorer program also provides a means of developing instruments for "payload-of-opportunity" missions, such as those involving other Federal agencies or international collaboration.

The San Marco-D mission, a cooperative project with Italy, was launched in March 1988 on Scout ELV to study the relationship between solar activity and meteorological phenomena on the Earth. After successfully completing its mission objective, the spacecraft reentered the Earth's atmosphere in December 1988. The Cosmic-Ray Isotope Experiment (CRIE) will be included in the Combined Release and Radiation Effects Satellite (CRRES), a joint NASA/DOD mission, now scheduled for an Atlas-Centaur launch to a geosynchronous transfer orbit (GTO) in FY 1990. The CRRES GTO mission will also release trace chemicals, whose transport in the magnetosphere can be observed from ground and airborne-based instruments.

In FY 1986, a new cooperative mission called Solar-A was initiated with the Japanese. Solar-A will be launched in FY 1991 to study the Sun during the upcoming solar maximum. The U.S. has selected an instrument for this spacecraft which will relate energetic solar phenomena and dynamic coronal structures seen in hard and soft x-rays to the topology of evolving solar magnetic fields. This will allow the first simultaneous observations of these phenomena from space.

In FY 1990, development continues on the Extreme Ultraviolet Explorer (EUVE), and on the x-ray imaging instrument to be flown on the German Roentgen Satellite (ROSAT). EUVE, scheduled for launch on a Delta ELV in FY 1991, will carry out the first detailed all-sky x-ray survey and provide in-depth studies on selected objects. The U.S. will provide one of the ROSAT instruments and the launch services; Germany will provide the spacecraft, telescope, and other instruments. Current plans call for ROSAT to be launched on a Delta ELV in FY 1990.

Phase C/D activities will be initiated in FY 1990 on the X-ray Timing Explorer (XTE). This mission could be ready for launch as early as FY 1994. XTE-unique aspects of Explorer Platform development are currently under definition and are being funded out of the Platform budget. Therefore, the Platform budget has been separated from the EUVE budget to reflect the full funding level for the Platform.

In addition to the traditional Delta-class explorers, the Explorer program will begin development of "small class" explorers (SMEX). While subject to more stringent constraints than Delta-class missions (weight, telemetry, power, etc.), it is anticipated that a significant number of scientifically exciting missions can utilize this capability and be developed on a short timescale. Fifty-one proposals were received in response to the Small Explorer Announcement of Opportunity (AO). Following peer review, three payloads were selected for development in Spring 1989. The first of these three missions, the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX), is scheduled for launch on a Scout rocket in FY 1992. The two subsequent missions, the Submillimeter Wave Astronomy Satellite (SWAS) and the Fast Auroral Snapshot Explorer (FAST), are to be launched following SAMPEX at approximately one-year intervals.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The planned launch of COBE was delayed until November 1989, necessitating a reallocation of FY 1990 funds. The EUVE budget decreased by $1.2 million to offset an Explorer Platform overrun due to technical problems. The XTE and the small Explorers were decreased by $1.0 million as a result of the general Congressional reduction and the sequestration implementation. The Solar-A budget was increased by $3.4 million due to instrument development problems. The "Other Explorers" line was reduced by $7.2 million to offset the COBE slip, Solar-A technical problems, and the general Congressional reduction for a net total reduction of $1.4 million to the Explorer program..

BASIS OF FY 1991 ESTIMATE

The EUVE instrument development activities and Explorer Platform fabrication will be completed and final integration and test activities will be initiated. The XTE will continue final design activities in preparation for a Critical Design Review (CDR) in late FY 1991. Solar-A (SXT) will complete final integration and test activities in preparation for a launch in late 1991. The Small Explorer (SMEX) program will be well underway as the first mission, SAMPEX, will deliver flight instruments and begin final integration with the spacecraft for a launch in mid-1992. CDRs will also be held for SWAS and FAST, the other SMEX missions, in preparation for launches in the mid-to-late 1993 timeframe.

BASIS OF FY 1991 FUNDING REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Hubble space telescope operations and servicing	88,500	113,200	112,800	159,700
Hubble space telescope data analysis	9,800	21,200	19,600	32,200
Astrophysics mission operations and data analysis	32,500	54,500	48,900	81,100
Space physics mission operations and data analysis	11,600	15,900	21,100	20,900
Total	142,400	204,800	202,400	293,900

OBJECTIVES AND STATUS

The purpose of the mission operations and data analysis effort is to conduct operations and analyze data received from physics and astronomy spacecraft after launch. The program also supports the operation of a number of spacecraft after their originally planned objectives have been achieved, for purposes of conducting specific investigations that have continuing high scientific significance. The funding supports the data analysis activities of many investigators at universities and other research organizations associated with astrophysics and space physics operational satellite projects. Actual satellite operations, including control centers and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support contracts.

FY 1990 will see Mission Operations and Data Analysis activities for five new missions: the Cosmic Background Explorer (COBE) launched in November 1989; the Hubble Space Telescope (HST) scheduled for March 1990; the Astro-1/Broad Band X-ray Telescope Shuttle payload in April 1990; the U.S. German Roentgen Satellite (ROSAT) in May 1990; the Gamma Ray Observatory (GRO) in June 1990; and the Combined Release and Radiation Effects Satellite (CRRES) in July 1990.

Space Physics research activities rely on data received from the Interplanetary Monitoring Platform (IMP), and the Dynamics Explorer which are still operational, the Active Magnetospheric Particle Trace Explorer (AMPTE), which ceased to operate in 1989, and the International Sun-Earth Explorers (ISEE-1&2)

which reentered in October 1987. IMP continues to provide the only available source of solar wind input measurements to the Earth. The ISEE-3 spacecraft, renamed the International Cometary Explorer (ICE), provided complementary solar wind measurements upstream of Comet Halley in 1986. The Space Physics MO&DA program also supports data analysis for the highly successful Solar Maximum Mission (SMM), which ended in November 1989.

In addition to the normal support required for mission operations, the Hubble Space Telescope (HST) program encompasses several unique aspects which must be provided in advance of the launch. The HST is designed to operate for fifteen years, requiring on-orbit maintenance of the spacecraft and on-orbit changeout of the scientific instruments. The HST will be used primarily by observers selected on the basis of proposals submitted in response to periodic solicitations. Science operations will be carried out through an independent HST Science Institute. The Institute operates under a long-term contract with NASA. While NASA retains operational responsibility for the observatory, the Institute implements NASA policies in the area of planning, management, and scheduling of the scientific operations of the HST.

Initiation of the definition and implementation of a unified data system which will ensure the fullest access and exploitation of the various mission data sets, with emphasis on the wealth of data to be returned by the Great Observatories, will be undertaken. An initial definition process involving extensive inputs from the astrophysics community has now been completed, and FY 1990 funding will enable the principal elements of this essential system to be put in place.

CHANGES FROM FY 1990 BUDGET ESTIMATE

All Physics and Astronomy Mission Operations & Data Analysis elements have been reduced to reflect the general Congressional reduction and the impact of sequestration. GRO funding was reduced by $2.9 million as a partial offset to the development increase resulting from the launch slip from April to June. Funds from the GGS program have been added to the Space Physics MO&DA program in FY 1990 to augment data analysis activities for the space plasma physics missions which are scientific precursors to the GGS program.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding level is required to support ongoing missions including COBE, HST, GRO, ROSAT, CRRES, and EUVE. Mission operations, data analysis, and guest investigator programs will continue for the Interplanetary Monitoring Platform (IMP), the Dynamics Explorer (DE), International Cometary Explorer (ICE), and the International Ultraviolet Explorer (IUE). The High Energy Astronomical Observatories (HEAO 1-3), International Sun-Earth Explorers 1 and 2 (ISEE-1 & 2), the Solar Maximum Mission (SMM), the Active Magnetospheric Particle Trace Explorer (AMPTE), and the Infrared Astronomy Satellite (IRAS) data analysis will also continue. These programs have produced valuable data sets which are used by a wide segment of the science community. FY 1991 funds will also be used to continue development of the unified astrophysics data system.

BASIS OF FY 1991 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Supporting research and technology.......	85,100	101,500	99,400	88,500
Advanced technology development..........	--	11,000	10,100	34,000
Total..................................	85,100	112,500	109,500	122,500

OBJECTIVES AND STATUS

This program provides for the preliminary studies required to define missions and/or payload requirements, as well as providing a research and technology base necessary to define, plan and support flight projects.

The objectives of supporting research and technology (SR&T) are to: (1) optimize the return expected from future missions through scientific problem definition, development of advanced instrumentation and concepts, and sound definition of proposed new missions; (2) enhance the value of current space missions by carrying out complementary and supplementary ground-based observations and laboratory experiments; (3) develop theories to explain observed phenomena and predict new ones; (4) strengthen the technological base for sensor and instrumentation development and conduct the basic research necessary to understand astrophysics phenomena and solar-terrestrial relationships; and, (5) continue the acquisition, analysis and evaluation of data from laboratories, balloons, rocket and spacecraft activities.

Research is supported in the disciplines of astronomy, astrophysics, gravitational physics, plasma, cosmic ray and solar physics. Research in astronomy and astrophysics involves the study of stars, galaxies, interstellar and intergalactic matter, and cosmic rays. Space physics research and analysis is a broadly structured effort to enhance our understanding of the characteristics and behavior of plasmas in the solar corona, the interplanetary medium and in the vicinity of the Earth and other planets. Theory activities are related to all the physics and astronomy disciplines and are critical to the correlation of available information. The development of new instruments, laboratory and theoretical studies of basic physical processes, and observations by ground-based and balloon-borne instruments will also be continued.

Results achieved in the SR&T program will have a direct bearing on future flight programs. For example, the development of advanced x-ray, ultraviolet, and infrared astronomy imaging devices under this program may enable spacecraft to carry instruments for astronomical observations which have increased orders of magnitude in sensitivity and improved resolution over currently available detectors.

One major thrust of the space physics program is directed at studies of the near-Earth geospace environment, from the flow of the solar wind past the magnetosphere, to variations of the plasma environment detectable near the surface of the Earth. Not only are these studies of great interest for basic plasma physics but there are also many practical ramifications, such as ionospheric influences on communication, global circulation of the atmosphere driven by magnetospheric input, the charging of spacecraft immersed in plasma, and the behavior of antennas and their signals in the magnetosphere.

The SR&T program carries out its objectives through universities, nonprofit and industrial research institutions, NASA centers and other government agencies. Current emphasis is being placed on studies of advanced instrumentation with increased sensitivity and resolution.

FY 1990 activities continue definition studies of the Stratospheric Observatory for Infrared Astronomy (SOFIA), Orbiting Solar Laboratory (OSL), and Space Infrared Telescope Facility (SIRTF).

The advanced technological development activities support detailed planning and definition of potential new physics and astronomy missions. ATD activities assure that future missions address the scientific questions most important to the evolution of knowledge in the field, and that those missions use the appropriate technology and techniques. Current activities are concentrated on AXAF observatory and instrument definition.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The $3.0 million decrease reflects by the general Congressional reduction and the impact of sequestration. This will be accommodated by the deferral of some planned research activities until FY 1991.

BASIS OF FY 1991 ESTIMATE

During FY 1991, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for viable physics and astronomy and space physics programs. FY 1991 funding will support continued studies on potential future missions. In the data analysis activities to be carried out at university and government research centers in FY 1991, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories). ATD funding will support the AXAF observatory definition, long-lead procurements and design studies at the mission contractor, TRW, Inc., leading to anticipated full-scale initiation of observatory development in FY 1992.

BASIS OF FY 1991 FUNDING REQUIREMENT

SUBORBITAL PROGRAM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Sounding rockets........................	27,000	30,500	30,100	31,300
Airborne science and applications........	9,800	10,900	10,700	11,500
Balloon program.........................	8,600	12,100	11,900	12,200
Total................................	45,400	53,500	52,700	55,000

OBJECTIVES AND STATUS

The suborbital program uses balloons, aircraft, and sounding rockets to conduct versatile, relatively low-cost research of the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high energy astrophysics. Activities are conducted on both a national and international cooperative basis.

A major objective of the sounding rocket program is to support a coordinated research effort. Sounding rockets are uniquely suited for performing low altitude measurements (between balloon and spacecraft altitude) and for measuring vertical variations of many atmospheric parameters. Special areas of study supported by the sounding rocket program include the nature, characteristics, and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including the production of aurorae and the coupling of energy into the atmosphere; and the nature, characteristics, and spectra of radiation of the Sun, stars and other celestial objects. Also included is support for NASA's final Spartan mission, Spartan 201, which consists of a 17-inch diameter solar telescope with an ultraviolet coronograph and a white light coronograph to measure the intensity and scattering properties of solar light. Spartan 201 is planned for Shuttle launch in the early 1990s.

Additionally, the sounding rocket program provides several Space Science and Applications programs with the means for flight testing instruments and experiments being developed for future flight missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. Approximately forty rockets are scheduled for launch in FY 1990.

Research with instrumented jet aircraft has been an integral part of the NASA physics and astronomy program since 1965. For astronomy research, the airborne science and applications program operates the Kuiper Airborne Observatory (KAO). This full-scale manned facility consists of a C-141 aircraft equipped with a 91-centimeter infrared telescope. The C-141's ability to fly for several hours at altitudes approaching 13 kilometers, provides a cloud-free site for astronomical observations above most of the infrared-absorbing water vapor in the Earth's atmosphere. This has been essential in expanding astronomical observations into the infrared region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1989, the C-141 conducted one major campaign in the southern hemisphere to continue studies of supernova SN1987a. The C-141 played a critical role in the continual effort to characterize the Supernova by measuring its velocity, morphology and composition. During FY 1989, the C-141 also observed a stellar occultation by the planet Saturn and its rings. Other observations included the exploration of the star-forming regions and of other areas in our own galaxy and solar system, as well as in external galaxies. In FY 1990, 72 missions are planned, including one southern hemisphere campaign. Also during FY 1990, the U.S. Air Force planned deposit maintenance will be completed.

The Balloon program provides a cost-effective means to test flight instrumentation in the space radiation environment and to make observations at altitudes which are above most of the water vapor in the atmosphere. Balloon experimentation is particularly useful when studying infrared, gamma-ray, and cosmic-ray astronomy. In many instances it is necessary, because of size, weight, cost, or lack of other opportunities, to fly primary scientific experiments on balloons. In addition to the level-of-effort science observations program, significant emphasis has been and will be placed on development of a balloon capable of lifting more than 3,500 pounds, and to support missions lasting several days.

The Balloon program funding is required for purchase of balloons, helium, launch services, tracking and recovery, as well as for maintenance and operations of the National Scientific Balloon Facility (NSBF) at Palestine, Texas, and remote launch sites. Funding for the experiments flown on balloons is provided from other research and technology programs supporting the various scientific disciplines.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The FY 1990 estimate reflects a $0.8 million general Congressional reduction and the impact of sequestration. This will require some reductions to planned performance enhancements for the Balloon program as well as the deferral of one or more sounding rocket and airborne missions.

BASIS OF FY 1991 ESTIMATE

FY 1991 funds will provide for continuation of the sounding rocket, Spartan, and balloon programs including management and operation of the NSBF. This funding is also required to continue definition activities for balloon improvement and long-duration balloon flights. In FY 1991, the Airborne Science and Applications funding will be used to continue flights of the KAO.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — LIFE SCIENCES

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Human space flight and systems engineering	28,600	42,800	40,678	71,000	RD 4-4
Space biological sciences	10,100	27,600	21,200	32,000	RD 4-4
Search for extraterrestrial intelligence	2,200	6,800	4,000	12,100	RD 4-4
Research and analysis	38,200	47,000	40,400	47,900	RD 4-7
Total	79,100	124,200	106,278	163,000	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	30,100	47,800	43,475	67,400
Kennedy Space Center	3,100	3,900	4,100	6,300
Marshall Space Flight Center	10	100	80	125
Goddard Space Flight Center	200	200	395	400
Jet Propulsion Laboratory	945	2,300	1,200	1,900
Ames Research Center	31,900	50,700	39,473	61,000
Lewis Research Center	84	--	100	150
Langley Research Center	351	500	440	700
Stennis Space Center	10	100	15	25
Headquarters	12,400	18,600	17,000	25,000
Total	79,100	124,200	106,278	163,000

OFFICE OF SPACE SCIENCE AND APPLICATIONS **LIFE SCIENCES**

OBJECTIVE AND JUSTIFICATION

The two major goals of the Space Life Sciences program are to develop medical and biological systems which enable human habitation in space and to advance the knowledge about the life processes of the universe. Results from the research program are applied to: the immediate needs of maintaining astronaut health and productivity; understanding the response of biological mechanisms to weightlessness; the development of environmental health requirements for space flight and design of controlled and bio-regenerative life support systems; understanding the origin, evolution and distribution of life in the universe; and understanding the biosphere of the planet Earth.

Continuing support of the Space Life Sciences program is essential to: understand the basic biological mechanisms of responses to gravitational forces; evolve the critical technologies necessary to enable long-term, piloted space flight; and, develop the capability to sustain a permanent manned presence in space. The research program studies fundamental biological processes through both ground-based and space research efforts which are mutually supportive and integrated.

The Space Life Sciences Research and Analysis program includes five major elements: 1) space medicine, which provides for the physical and environmental health of space crews by seeking to understand and prevent adverse environmental and/or physiological changes which occur in space flight and upon return to Earth; 2) space biology, a multidisiplinary basic research program of the fundamental mechanisms of gravitational interactions; 3) controlled ecological life support systems, a program of research and critical technology development for life support systems necessary to maintain life in space autonomously for long periods of time; 4) exobiology research, which is directed toward understanding the origin and distribution of life and life-related molecules on Earth and throughout the universe; and, 5) biospheric research, which explores the interaction between life on Earth and its physical and chemical environment.

The Space Life Sciences Flight program, consisting of research in human space flight and systems engineering and space biological sciences, provides scientific and engineering support to select, define, develop and conduct in-space experiments designed to provide answers to medical and biological issues related to the microgravity environment. The flight program is actively preparing experiments for launch on Spacelab missions in 1990, 1991 and 1992. Definition activities are underway to develop payloads for

later Spacelab missions and early Space Station utilization. Experiments are currently conducted on the Shuttle and Spacelab, and are being prepared for transition to the Space Station Freedom. An international cooperative program, with the European Space Agency (ESA), Centre National d'Etudes Spatiales (CNES), Deutsche Forschungsund Versuchsanstalt fur Luft-und Raumfahrt (DFVLR), Canadian Space Agency (CSA), The National Space Development Agency of Japan (NASDA), and the Union of Soviet Socialist Republic (U.S.S.R.) pursues investigations of common interest. With the U.S.S.R., we have a vigorous program aimed at solving biomedical problems associated with long duration missions utilizing the MIR Space Station and ground based research.

The Life Sciences program is currently supporting and expanding its activities in establishing NASA Specialized Centers of Research and Training (NSCORT) at select universities. One focus of the program is to attract a larger segment of the scientific community to participate in space programs and contribute to the training of new generations of space life scientists. In addition, the program will offer an opportunity to establish specialized interdisciplinary centers of excellence. Cooperative programs are underway with the National Institutes of Health to utilize the space environment to study the role that gravity might play in health and diseases on Earth. Additional NSCORT programs in environmental health of spaceflight and life support technologies are also being established.

BASIS OF FY 1991 FUNDING REQUIREMENT

SPACE LIFE SCIENCES FLIGHT PROGRAM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Human space flight and systems engineering	28,600	42,800	40,678	71,000
Space biological sciences	10,100	27,600	21,200	32,000
Search for extraterrestrial intelligence	2,200	6,800	4,000	12,100
Total	40,900	77,200	65,878	115,100

OBJECTIVES AND STATUS

The objective of the Space Life Sciences flight program is to develop payloads designed to expand the understanding of the basic physiological mechanisms involved in adaptation to weightlessness. The program also includes selection, definition, in-flight operation, data analysis and reporting on medical and biological investigations involving humans, animals, and plants. Human space flight and systems engineering activities advance NASA's ability to extend the duration, enhance the performance, and improve the safety of human space flight. Past experience indicates that humans clearly undergo physiological changes during weightlessness. Many of the observed changes are physiologically significant and are not well understood. Shuttle/Spacelab and Space Station Freedom are suitable platforms for gaining a greater understanding of the basic mechanisms underlying this response to weightlessness. Space biological sciences flight activities use the space environment, especially weightlessness, to further basic understanding of fundamental biological processes. Such flight experiments lead to a better understanding of the underlying mechanisms of gravitational adaptation, enhance our basic science knowledge, make it possible to improve life in space and on Earth, and increase the confidence with which we can estimate the physiological consequences of more sustained weightless exposure and design corresponding countermeasures.

FY 1990 activities include the final preparation and flight of approved experiments on the first dedicated Life Science mission (Spacelab Life Sciences-1 (SLS-1)) which is scheduled to be launched in August 1990 and will concentrate on studies of biomedical responses, with emphasis on cardiovascular, bone metabolism and vestibular functions. Spacelab Life Sciences-1 will be unique in several respects: it

will be the first Shuttle/Spacelab mission dedicated entirely to life sciences, and it will involve highly skilled scientists as payload specialists, thus permitting the use of numerous experimental techniques and procedures never before utilized in space. Many of the experiments and associated flight hardware flown on earlier Shuttle flights will support and enhance preparations for SLS-1 and subsequent missions.

In FY 1990, under the Human Space Flight and Systems Engineering program, efforts will continue in a major new area of research - ensuring Shuttle crew performance in orbit and upon landing on extended duration orbiter (EDO) missions. Investigations will proceed in Spacelab and Space Transportation System (STS) middeck areas with the operational goal of enabling extended duration missions in time for the U.S. Microgravity Lab-1 mission in 1992. Definition activities will also begin on the feasibility of extending operational tours of duty of flight crews on the Space Station Freedom (SSF) in order to achieve greater cost-effectiveness. The program, known as Biomedical Monitoring and Countermeasures (BMAC), will allow more effective use of human resources by maintaining crew health and productivity with countermeasures that minimize impact on in-flight crew time. Crew debility and rehabilitation time following long duration space flight will also be reduced. Spacelab opportunities will be used to conduct supporting experiments and fly associated payloads. Preparation for the Space Station will commence with investigation planning, technology assessment for flight equipment, and critical technology and hardware development.

Beginning in FY 1990, the Search for Extraterrestrial Intelligence (SETI) project, previously funded under the Research and Analysis budget, will be separately identified in the Life Sciences program. The Search for Extraterrestrial Intelligence will employ NASA's existing radio astronomy facilities as well as Deep Space Network antennas to analyze microwave signals in space for evidence of advanced life elsewhere in the galaxy. The Search for Extraterrestrial Intelligence will begin the C/D phase of construction of advanced signal processing systems and is expected to be partially operational by 1992 to coincide with the five-hundredth anniversary of Columbus' discovery of America. In FY 1991, the SETI project will initiate a major hardware procurement phase.

CHANGES FROM FY 1990 BUDGET ESTIMATE

As a result of Congressional actions and the impact of the FY 1990 sequestration, there will be an $11.3 million reduction in the flight program. This reduction necessitates reduced support for definition of the Space Biology Initiative (SBI), and delay of the full initiation of the C/D phase of the SETI project by at least one year. Life Sciences participation on the International Microgravity Laboratory-2 (IML-2) mission in 1993 has been reduced to Extended Duration Orbiter (EDO) studies. The joint U.S./French experiment, originally scheduled for IML-2, has been rescheduled to fly on the Spacelab Life Sciences-3 (SLS-3) mission in 1994. These changes will preserve resources for near-term Spacelab missions beginning with SLS-1 in August of 1990. Plans for a fifth SLS mission in 1996 have been cancelled.

BASIS OF FY 1991 ESTIMATE

Final preparations are underway to support the flight of the first IML-1 mission in 1991. Approximately 50 percent of the payload relates to space life sciences, with the U.S. focus on plants, neurovestibular studies, human performance, radiation and cellular differentiation.

Efforts will continue on definition and development of new experiments, selected through the Announcement of Opportunity (AO) process, and hardware that will be flown on several future Spacelab/Shuttle missions in FY 1991 and 1992 - i.e.; Shuttle middecks, the Japanese SL-J mission, the second dedicated life sciences mission (SLS-2), the German D-2 mission, IML-2 and SLS-3. Collaboration with the Soviet Union on its COSMOS biosatellite program will continue with joint research on COSMOS and Space Station MIR flights in 1990, 1991, and 1992. Mission studies continue on Lifesat, the reusable reentry satellite for life sciences research, in preparation for initiation of development activities in FY 1992. The Lifesat, a polar-orbiting biosatellite, will first be launched on a Delta II in late 1994. The biosatellite will contain living biological specimens, including plants, rodents, cell and tissue cultures, and other small organisms, which will be used to study the effects of high-energy galactic cosmic rays on living matter. This information is required to determine astronaut radiation-exposure limits and possible countermeasures to radiation.

In FY 1991, under the Space Biological Sciences program, development will continue on an integrated centrifuge facility for SSF that will support a broad spectrum of life sciences research using small animals and plants. This facility will provide continuous on-board 1-G control that can separate influences of weightlessness from other effects of space flight. It will allow scientists to test the response of living organisms to operational forces at various stages of adaptation to weightlessness. This facility represents a marked enhancement of basic research capability to the Life Sciences program, and has been a top priority recommendation of the National Academy of Sciences for life sciences research for several years.

Definition and long lead development will begin in FY 1991 for SSF requirements. Studies will identify unique scientific and hardware transition requirements from continuing Spacelab flights to Space Station operations. In addition, technology assessment, advanced technology development, hardware definition, and experiment definition and planning will be conducted.

BASIS OF FY 1991 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space life sciences research and analysis...............................	38,200	47,000	40,400	47,900

OBJECTIVES AND STATUS

The research and analysis activity supports the Space Life Sciences program goals of: advancing knowledge in all areas of space life sciences and developing medical and biological systems which enable human habitation in space. The program is composed of five elements: 1) space medicine; 2) space biology; 3) environmental health and controlled ecological life support systems research; 4) exobiology; and, 5) biospheric research.

The Space Medicine program is responsible for assuring the physical welfare, performance, and treatment of in-flight illness or injuries of spaceflight crews. Such conditions as space motion sickness, spatial disorientation, fluid shifts and endocrine changes, can decrease performance and cardiovascular tolerance and possibly aggravate latent disease. These conditions must be carefully evaluated to determine preventative measures. To this end, careful medical selection, periodic evaluation of health status, and in-flight monitoring of the adaptation to space and success of physiological countermeasures will be continually undertaken. In addition, long-term monitoring of space flight crews will be performed in a standardized fashion in order to identify risk factors and establish the long-term clinical significance associated with repeated exposure to the space environment. Biomedical research will investigate the fundamental physiological basis for problems encountered in manned spaceflight. Research areas include: clinical medicine; neuroscience; cardiopulmonary, musculoskeletal, and regulatory physiology; cell and developmental biology; behavior, performance and human factors; and, radiation and environmental factors.

The Space Biology program explores the role of gravity in life processes and uses gravity variations as an environmental tool to investigate fundamental biological questions. Specific objectives are to perform the basic science research required to identify and investigate: 1) the role of gravity in plant and animal behavior, morphology, development and physiology; 2) the mechanisms of gravity sensing and the transmission of this information within both plants and animals; 3) the interactive effects of gravity

and other stimuli (e.g., light) and stresses (e.g., vibration and disorientation) on the physiology of organisms; 4) the uses of gravity to study the normal nature and properties of living organisms; and, 5) the effects of microgravity to facilitate plant and animal growth, long-term survival and reproduction in space.

The Environmental Health and Controlled Ecological Life Support Systems program seeks to control the toxicological and microbiological environment of spacecraft within the prescribed limits and to provide air, water and food to support life through bioregenerative closed systems which receive only energy from the external environment. Development of such systems is a critical path element for long duration manned spaceflight and lunar colonization.

The Exobiology program is directed toward understanding the origin and evolution of life and life-related molecules, on Earth and throughout the universe. Research seeks to trace the pathways leading from the origin of the universe through the major epochs in the evolution of living systems. Research encompasses the cosmic evolution of the biogenic compounds, prebiotic evolution, early evolution of life, and evolution of advanced life. Emphasis is placed on understanding these processes in the context of the planetary and astrophysical environments in which they occurred. Flight experiments in Earth orbit and on planetary missions are important program elements. Theoretical and laboratory investigations are also included in this program to develop a better understanding of the conditions on Earth as related to early chemical and biological evolution.

The Biospheric Research program explores the interaction between global biological and planetary processes to develop an understanding of global biogeochemical cycles. Laboratory and field investigations are correlated with remote sensing data to characterize the influence of biological processes in global dynamics. Biospheric modeling efforts integrate biological data with atmospheric, climate, oceanic, terrestrial, and biogeochemical cycling data to reflect the state of the biosphere as a function of both natural and anthropogenic perturbations.

CHANGES FROM FY 1990 BUDGET ESTIMATE

As a result of Congressional actions and the FY 1990 sequestration, the Research and Analysis program has been reduced by $6.5 million resulting in reduced support for principal investigators as well as a minor delay in the NSCORT program.

BASIS OF FY 1991 ESTIMATE

In order to keep pace with the complex demands of a major new initiative for human exploration of the solar system, the basic research effort in life sciences must expand. Several questions about human adaptation to living beyond Earth will have to be answered. Among the questions are the relative benefits of artificial gravity versus the development of countermeasures to physiological deconditioning, life support closure versus the resupply of consumables, on-site medical care versus a rescue approach, and the psychological effects of prolonged isolation and confinement.

The Space Medicine program will resume collecting information on occupational exposure in microgravity on each Shuttle flight and conduct in-flight clinical testing of countermeasures, especially in the area of vestibular dysfunction, cardiovascular deconditioning and muscular atrophy. Resolving problems associated with the initial adaptation to weightlessness such as space motion sickness and fluid shifts will continue to be of high priority. Research emphasis will be placed on operational management of space adaptation syndrome. Approaches such as autogenic (biofeedback) techniques will be evaluated in flight to provide a basis for development of specific countermeasures. Research will commence in the field of biomechanics. Understanding the dynamics of bodily adaptation to physical forces and being able to measure stress on the human body is crucial to designing countermeasures to maintain astronaut health and productivity. Research in the fields of psychology and the ergonomics of man/machine interface will be supported for their importance in improving the performance and efficiency of flight crews. Research in radiation biology will continue because it is necessary to precisely measure dosages and the effects of cosmic and solar radiation in order to determine the optimum radiation shielding required for humans in space. Research is in progress to lead development of pressurized space suits for quick reaction situations and to develop corresponding pressurized suit gloves.

In conjunction with NASA's development of the EDO and the Space Station, the Space Medicine program will support extended crew time in space with extensive research in the physiological changes associated with longer exposure to weightlessness. Bone demineralization, muscle atrophy, neurovestibular disturbances and cardiovascular deconditioning will be studied in ground-based simulation so that appropriate countermeasures can be designed. This accelerated program of directed research, bed rest studies and protocol development and evaluation will allow more effective use of human resources in space by developing physiological countermeasures that minimize impact on in-flight crew time. Critical technology requirements will be addressed and research on implementation initiated.

The Space Biology program will concentrate ground research on: developing working models of functioning gravity-sensing neural (information) networks to understand neurosensory processing in microgravity; understanding the physiological side effects of centrifugation in preparation for use of the Shuttle/Space Station centrifuge as a research tool; and identifying the cellular events of the gravity perception mechanism in plants. Research in preparation for flight opportunities on the Shuttle and the Soviet biosatellite COSMOS will focus on genetic, cytological, developmental and metabolic effects of gravity on plants and animals. Fundamental research in gravitational response mechanisms in plant and animal development will be developed in preparation for future biosatellite and Space Station experiments.

The Controlled Ecological Life Support Systems program will continue to investigate basic biological processes and physical methods to control the interior environment of manned spacecraft. In developing such a life support system, the near term emphasis will be on system definition and development of design concepts and critical technologies for flight, and supporting research in the areas of controlled-environment plant production, waste processing and human nutrition.

The Exobiology program will emphasize the development of new flight experiment concepts to investigate models of early Solar System evolution and mechanisms for the synthesis of biologically significant molecules in space. The program will further develop analytic capabilities to utilize an expanding extraterrestrial sample base, participate in the retrieval of samples, and focus science on emerging opportunities in planetary exploration.

The Biospheric Research program will place emphasis on improving estimating techniques for determining the structural state of the terrestrial biomass by combining ground-based measurements at tropical, temperate, and wetland sites with remote sensing data and biogeochemical modeling of the interactions of ecosystems on a global scale. Information gathered through remote sensing will also be used to help nations prepare for outbreaks of malaria by allowing predictive modeling of the occurrence of mosquitoes.

In FY 1991, NASA Specialized Centers of Research and Training (NSCORT) at universities will support long-term, broad-based interdisciplinary research on selected high priority research topics. The NSCORT program, which is modeled on the highly successful National Institutes of Health program, will help increase science results by concentrating resources, facilities and personnel on focused research problems. The NSCORTs will conduct research in the following science programs: biomedical, operational medicine, space biology, exobiology, biospherics, and controlled ecological life support systems.

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PLANETARY EXPLORATION

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Galileo development	73,400	17,400	17,127	--	RD 5-5
Magellan	43,100	--	--	--	
Ulysses	10,300	14,500	14,252	3,300	RD 5-7
Mars observer	102,200	100,500	98,922	68,900	RD 5-9
Mars balloon relay	--	--	4,400	2,000	RD 5-9
Comet rendezvous asteroid flyby/cassini	--	30,000	29,519	148,000	RD 5-11
Mission operations and data analysis	110,700	155,400	156,856	173,500	RD 5-13
Research and analysis	76,900	79,100	70,610	89,500	RD 5-15
Total	416,600	396,900	391,686	485,200	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	9,312	9,100	8,996	9,400
Marshall Space Flight Center	134	150	150	160
Goddard Space Flight Center	17,870	17,500	17,291	18,200
Jet Propulsion Laboratory	326,324	308,950	304,833	393,440
Ames Research Center	15,074	13,700	13,543	14,200
Langley Research Center	25	--	--	--
Headquarters	47,861	47,500	46,873	49,800
Total	416,600	396,900	391,686	485,200

OBJECTIVES AND JUSTIFICATION

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteroids, and the interplanetary medium. The program objectives are: (1) to determine the nature of planets, comets, and asteroids as a means for understanding the origin and evolution of the solar system; (2) to better understand the Earth through comparative studies with the other planets; (3) to understand how the appearance of life in the solar system is related to the chemical history of the solar system; and, (4) to provide a scientific basis for the future use of resources available in near-Earth space. Projects undertaken in the past have been highly successful based on a strategy that places a balanced emphasis on the Earth-like inner planets, the giant gaseous outer planets, and the smaller bodies (comets and asteroids). Missions to these bodies start at the level of reconnaissance to achieve a fundamental characterization of the bodies, and then proceed to levels of more detailed study.

The reconnaissance phase of inner planet exploration, which began in the 1960's, is now virtually completed, although we still know little about the nature of the planet Venus' surface. Mars has provided program focus because of its potential as a site of biological activity. The Viking landings in 1976 carried the exploration of Mars forward to a high level of scientific and technological achievement, thereby setting the stage for the next step of detailed study. Analyses of meteorites and the lunar rock samples returned by Apollo continue to be highly productive, producing new insights into the early history of the inner solar system and thus leading to revision of our theoretical concepts. The Pioneer Venus mission is continuing to carry the study of the Earth's nearest planetary neighbor and closest planetary analog beyond the reconnaissance stage to the point where we have now obtained a basic characterization of Venus' thick, massive atmosphere, as well as fundamental data about the formation of the planet.

The exploration of the giant outer planets began more recently. The Pioneer-10 and -11 missions to Jupiter in 1973 and 1974 were followed by the Voyager-1 and 2 spacecraft encounters in 1979. Voyager-1 then encountered Saturn in November 1980, and Voyager-2 in August 1981. The Voyager data on these planets, their satellites, and their rings have revolutionized our concepts about the formation and evolution of the solar system. Voyager-2 encountered Uranus in January 1986 and provided our first look at this giant outer planet. Its trajectory carried it to an encounter with Neptune in August 1989 and provided spectacular images of this mysterious planet and its satellites. The Pioneer-10 and 11 and Voyager-1 spacecraft are on trajectories heading out of the solar system as they continue to return scientific data about the outer reaches of our solar system.

Magellan, launched in May 1989 from the Shuttle with an IUS, will provide global maps of the cloud-shrouded surface of Venus, including its land forms and geological features. Using a synthetic aperture radar to penetrate the planet's opaque atmosphere, Magellan will achieve a resolution sufficient to identify small-scale topographical features which will address fundamental questions about the origin and evolution of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's gravity field as well as internal stresses and density variations so that the evolutionary history of Venus can be compared with that of the Earth.

Galileo was launched on a Shuttle/Inertial Upper Stage (IUS) combination in October 1989 on a trajectory using gravity assists at Venus and Earth. The comprehensive science payload will extend our knowledge of Jupiter and its system of satellites well beyond the profound discoveries of the preceding Voyager and Pioneer missions. During twenty-two months of operation in the Jovian system, Galileo will inject an instrumented probe into Jupiter's atmosphere to make direct analyses, while the orbiter will have the capability to make as many as ten close encounters with the Galilean satellites.

Ulysses is a joint NASA/European Space Agency (ESA) activity. The mission will carry a package of experiments to investigate the Sun at high solar latitudes that cannot be studied from the Earth's orbit. Ulysses will be launched in October 1990 using the Shuttle and IUS/PAM-S launch stages.

Mars Observer will follow up on the earlier discoveries of Mars by Mariner 9 and Viking and will emphasize the geologic and climatic evolution of this complex planet. The mission will utilize a modified Earth-orbiting spacecraft, thereby benefiting from the previously developed technology. This mission was recently augmented to accommodate the Mars Balloon Relay (MBR) experiment. The French-supplied hardware will be incorporated into the existing payload and will allow Mars Observer to act as a data relay station for data returned from the balloon stations of the U.S.S.R. 1994 Mars mission. Mars Observer will be launched in 1992, using a Titan III launch vehicle with a TOS upper stage.

In FY 1990, development began on the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini (the Saturn Orbiter/Titan Probe) missions for launches in August 1995 and April 1996, respectively. Both missions will provide new understanding into the origin of the solar system which may provide new clues to the origin of life as well.

Mission operations and data analysis activities continue to support the Voyager and Pioneer missions as well as the recently-launched Galileo and Magellan spacecraft now enroute to Jupiter and Venus, respectively. Planetary flight support activities also continue to provide ongoing design, development and maintenance of ground support hardware and software for mission control, telemetry and command functions for all planetary spacecraft. As part of the Human Exploration Initiative (HEI), funding will also support initial Mars Observer operations upgrades to facilitate the selection of landing sites for future missions.

Beginning in late 1985, we entered an exciting new phase of exploration by making our first close-up studies of the solar system's mysterious small bodies -- comets and asteroids. These objects may represent unaltered original solar system material, preserved from the geological and chemical changes that have taken place in even small planetary bodies. By sampling and studying comets and asteroids, we can begin to make vigorous inquiries into the origin of the solar system itself. These efforts began with the encounter of Comet Giacobini-Zinner by the International Comet Explorer (ICE) spacecraft in September 1985 and continued through our involvement with the 1986 encounters and observations of Comet Halley by U.S. and foreign spacecraft and by intensive studies of the comet from ground-based observatories coordinated through the International Halley Watch. Studies of results obtained by these missions and observations and the archiving of these data are ongoing.

As part of the Human Exploration Initiative (HEI), funds have been provided to support studies for the Lunar Observer mission for a planned new start in FY 1992. Feasibility studies for future Mars missions will also continue.

BASIS OF FY 1991 FUNDING REQUIREMENT

GALILEO DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spacecraft	34,880	6,200	6,200	--
Experiments	13,670	3,300	3,300	--
Ground operations	24,850	7,900	7,627	--
Total	73,400	17,400	17,127	--
Mission operations and data analysis	(--)	(39,200)	(38,000)	(48,200)
Space transportation system operations	(85,500)	(--)	(--)	(--)
Upper stage	(18,200)	(17,400)	(20,200)	(900)

OBJECTIVES AND STATUS

The objective of the Galileo program is to conduct a comprehensive exploration of Jupiter, its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and *in situ* measurements by an atmospheric probe. The scientific objectives of the mission are based on recommendations by the National Academy of Sciences to provide continuity, balance, and orderly progression of the exploration of the solar system.

The spacecraft was launched in October 1989 using a Shuttle/Inertial Upper Stage (IUS) combination on an initial trajectory toward Venus, to be followed by two Earth swingbys. The three gravitational assists will provide the energy required for a trajectory to Jupiter not otherwise obtainable with this launch vehicle combination. When the orbiter arrives at Jupiter in late 1995, it will provide remote sensing of the probe entry site and provide the link for relaying the probe data back to Earth. Twenty-two months of orbital operations will follow during which Jupiter's dynamic magnetosphere and four major satellites will be extensively mapped. During this time, up to ten close flybys of Jupiter's four major satellites are targeted.

The Galileo flight system is powered by two general purpose heat-source Radioisotope Thermoelectric Generators (RTG's) developed by the Department of Energy. The orbiter carries approximately 100 kg of scientific instruments and the probe contains approximately 25 kg of scientific instruments.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $0.3 million due to the general Congressional reduction. This was accommodated by a decrease in funding for ground operations activities.

BASIS OF FY 1991 FUNDING REQUIREMENT

ULYSSES DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spacecraft..............................	4,230	5,600	5,530	--
Experiments............................	3,885	3,500	3,500	1,000
Ground operations.....................	2,185	5,400	5,222	2,300
Total..................................	10,300	14,500	14,252	3,300
Space transportation system operations...	(32,500)	(90,100)	(89,800)	(--)
Upper stage............................	(26,300)	(22,100)	(9,100)	(14,400)

OBJECTIVES AND STATUS

Ulysses is a joint mission of NASA and the European Space Agency (ESA). ESA is providing the spacecraft and some scientific instrumentation. The U.S. is providing the remaining scientific instrumentation, the launch vehicle and support, tracking support, and the Radioisotope Thermoelectric Generator (RTG). The mission is designed to obtain the first view of the Sun above and below the plane in which the planets orbit the Sun. The mission will study the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude, to provide a better understanding of solar activity on the Earth's weather and climate.

Ulysses was restructured in FY 1981 from a two-spacecraft mission--one provided by the United States and one provided by ESA--to a single ESA spacecraft mission. However, the United States' participation in the program remains substantial. NASA is responsible for five of the nine principal investigator instruments, and three of the four European investigations have U.S. co-investigators.

The Ulysses launch is planned for October 1990, using the Shuttle and IUS/PAM-S launch stages. During 1990, support to ESA is continuing to make the spacecraft compatible with the new upper stage configuration. Launch approval activities involving the RTG, and support for retesting the spacecraft and the science instruments are also continuing.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a $0.3 million reduction due to the general Congressional reduction. This was accommodated by reductions to spacecraft and ground operations funding.

BASIS OF FY 1991 ESTIMATE

FY 1991 funding will support the Ulysses launch in October 1990 and initial checkout of the spacecraft and instrument systems.

BASIS OF FY 1991 FUNDING REQUIREMENT

MARS OBSERVER DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spacecraft	60,605	61,000	59,522	31,200
Experiments	36,095	30,900	30,900	28,400
Ground operations	5,500	8,600	8,500	9,300
Total	102,200	100,500	98,922	68,900
Mars balloon relay experiment	--	--	4,400	2,000
Launch vehicle	(5,000)	(44,700)	(44,100)	(98,000)
Upper stage	(12,800)	(12,000)	(24,000)	(23,300)

OBJECTIVES AND STATUS

The Mars Observer mission is the first in a series of planetary observer missions utilizing a lower cost approach to inner solar system exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well defined and focused set of science objectives and uses modified production-line Earth-orbital spacecraft and instruments with previous spaceflight heritage. The objectives of the Mars Observer mission are to extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, atmospheric structure and circulation, topography, figure, gravity and magnetic fields of Mars to determine the location of volatile reservoirs and observe their interaction with the Martian environment over all four seasons of the Martian year.

The Mars Balloon Relay (MBR) experiment will be incorporated into the Mars Observer mission and will permit a significant increase in the amount of data returned from the balloon stations of the U.S.S.R. 1994 Mars mission. The MBR data will be routed through the Mars Observer Camera data stream for transmission back to Earth. Receiver and antenna hardware provided by France (CNES) will be accommodated on the Mars Observer spacecraft for MBR operations at the conclusion of the Mars Observer nominal mission in 1995. In support of the Human Exploration Initiative (HEI), funding has also been added for mission operations enhancements to provide additional science data required for the design of future Mars missions (see Mission Operations page RD 5-14).

Mars Observer will be launched in 1992 on a Titan III with a Transfer Orbit Stage (TOS). The spacecraft will be inserted into a near-polar Martian orbit in 1993, from which it will carry out geochemical, geophysical, and climatological mapping of the planet over a period of approximately one Martian year, which is nearly two Earth-years.

FY 1990 funding is providing for initial fabrication of the instrument hardware and for continuation of system design of the overall mission. Fabrication activities on the spacecraft, instruments and ground systems will be continued. MBR funds will be used to accommodate the French-supplied hardware into the Mars Observer spacecraft. Documentation will be developed and finalized for the hardware interface with the spacecraft and with the Mars Observer Camera instrument and engineering model testing of these interfaces will be conducted. Funding will also provide for integration of the MBR hardware into the spacecraft at the spacecraft contractor's plant.

CHANGES FROM FY 1990 BUDGET ESTIMATE

Mars Observer funding has been reduced by $1.6 million due to the general Congressional reduction. This was accommodated by reducing spacecraft and ground operations funding. MBR funds were added in the FY 1990 initial operating plan to complete detailed hardware design and modification activities and initiate hardware integration.

BASIS OF FY 1991 ESTIMATE

FY 1991 funding will support the completion of spacecraft and instrument final integration and test activities. Fabrication of the spacecraft, instruments and ground system will be completed. MBR funds will support the continuation of integration and test activities in support of a 1992 launch.

BASIS OF FY 1991 FUNDING REQUIREMENT

COMET RENDEZVOUS ASTEROID FLYBY/CASSINI DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spacecraft	--	19,800	19,400	94,300
Experiments	--	8,100	8,100	47,800
Ground operations	--	2,100	2,019	5,900
Total	--	30,000	29,519	148,000
Launch vehicle	(--)	(2,100)	(2,100)	(9,200)
Upper stage	(--)	(--)	(--)	(6,300)

OBJECTIVES AND STATUS

During the 1970's, our Nation established scientific and technological leadership in exploration of the outer solar system. The CRAF/Cassini program will extend our leadership in important ways during this critical period in solar system science. CRAF will be launched in August 1995, fly closely past the asteroid Hamburga in 1998, and rendezvous and fly in formation with the Comet Kopff in 2000 for two years of intensive study. During this period, CRAF will deliver a penetrator to study, for the first time, the interior composition of comet nucleus. Cassini will be launched in April 1996, fly past the asteroid Maja in 1997, gain gravity-assist from Jupiter in 2000 while observing this planet, and arrive at Saturn in 2002 for four years of study of the Saturnian system. After achieving an orbit around Saturn, Cassini will eject a probe to pass down through the atmosphere of Saturn's moon Titan, measure atmospheric composition, and gain the first images of Titan's surface. The orbiting spacecraft will use radar to map most of Titan's surface.

The CRAF/Cassini program, building upon the discoveries made through the Pioneer and Voyager spacecraft, will provide unprecedented information on the evolution of our solar system and will help determine if the necessary building blocks for the chemical evolution of life exist elsewhere in the universe. The CRAF-Cassini targets (comet, Titan, Saturn system) have a common origin in the outer solar system. The icy conditions on all the small bodies preserve a record of different stages and processes occurring during solar system formation and evolution. CRAF will provide the first long-term study of a comet, its undisturbed nucleus, and the nature and behavior of its ejected gases. It will enable direct analysis of the best-preserved primordial solar system material, possibly including interstellar matter. Thus, it may

be possible to assess organic molecules present at the beginning of the solar system and their potential contributions to the origin of life. Cassini will provide intensive, long-term observation of Saturn's atmosphere, rings, magnetic field, and moons. The Cassini probe will enable direct physical and chemical analysis of Titan's methane rich, nitrogen atmosphere which is a possible model for the pre-biotic stage of Earth's atmosphere. Through the joint study of origins with CRAF and early processes with Cassini, the program will improve our understanding of the early evolutionary process of our solar system.

Both missions will use virtually identical Mariner Mark II spacecraft with common design, fabrication, test, and integration team elements. Science instruments for CRAF have been tentatively selected. Cassini instruments will be selected in late 1990.

The CRAF/Cassini program has strong components for international cooperation. The Federal Republic of Germany has agreed to provide the propulsion system and one science instrument for CRAF and may do the same for Cassini. The European Space Agency (ESA) has selected the Cassini probe as its major new science program for this year at an estimated total cost of about $200 million. Furthermore, ESA member states will contribute about $75 million worth of science instruments and scientist participation.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a $0.5 million reduction due to the general Congressional reduction. This was accommodated by reduction to spacecraft and ground operations funding.

BASIS OF FY 1991 ESTIMATE

FY 1991 funding is required to continue design and development activities of the CRAF and Cassini spacecraft leading to an August 1995 launch to the comet Kopff and an April 1996 launch to Saturn. A selection of the tentative science instrument payload for the CRAF mission has been made and development will proceed in FY 1991. The Cassini Announcement of Opportunity (AO) was released in October 1989, and instruments will be selected early in FY 1991.

BASIS OF FY 1991 FUNDING REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Galileo operations	--	39,200	38,035	44,200
Magellan operations	17,100	37,800	41,207	32,700
Ulysses operations	--	--	--	8,900
Mars observer operations	--	--	--	15,000
Voyager extended mission	2,300	--	--	--
Pioneer programs	8,300	9,800	9,406	10,300
Voyager/Neptune mission	40,100	9,300	8,834	5,300
Voyager interstellar mission	--	15,000	16,658	14,300
Planetary flight support	42,900	44,300	42,716	42,800
Total	110,700	155,400	156,856	173,500

OBJECTIVES AND STATUS

The objectives of the mission operations and data analysis program are in-flight operation of planetary spacecraft and the analysis of data from these missions. The planetary flight support activities are those associated with the design and development of planetary flight operation systems, and other activities that support the mission control, tracking, telemetry, and command functions for all planetary spacecraft.

Operations for Galileo began in FY 1990 for the spacecraft's long journey to Jupiter. Galileo was launched by the Shuttle/Inertial Upper Stage (IUS) in October 1989 and will arrive at Jupiter in 1995 where it will conduct comprehensive exploration of that planet. Three gravitational assists will provide the energy required for Galileo's trajectory to the Jovian system.

Operations will continue for the Magellan spacecraft which was launched in May 1989 by the Shuttle/IUS on a trajectory to Venus. Arriving at Venus in August 1990, the spacecraft will map a major portion of the planet over a 243 day period (one Venus year) with a ground resolution of about 150 meters.

FY 1990 funds also support the two Voyager spacecraft which are now on trajectories that will take them into interstellar space. Voyager 1 continues to provide data on the interplanetary medium in that distant part of the solar system. Voyager 2 completed its grand tour of the solar system when, in August 1989, it made a spectacular close flyby of Neptune, providing our first detailed images of this distant planet. Highlights of this encounter included discovery of several previously unknown moons, and geyser-like surface eruptions. Voyager 2, now designated as the Voyager Interstellar Mission (VIM), will be on a trajectory which will extend exploration beyond the outer limits of the Sun's sphere of influence. The principal objectives of the VIM are to investigate and characterize the outer solar system particles and fields environment and interstellar media, to provide data on the location of the heliopause in conjunction with Pioneer-10 and -11, and to continue the successful Voyager program of ultraviolet astronomy.

Pioneers 10 and 11 continue to explore the outermost edge of the solar system. Pioneer 10 will soon encounter the unexplored region beyond Pluto where the Sun's influence is secondary to those of true interstellar space. These spacecraft will continue the search for gravitational evidence of a tenth planet. Pioneers 6-9 are still collecting information on the interplanetary magnetic field and solar wind as they orbit the Sun. The Pioneer Venus orbiter continues to obtain data on Venus' atmosphere and magnetosphere and its interaction with the solar wind. Pioneer Venus was also the only spacecraft able to observe the Comet Halley at its closest approach to the Sun in 1985.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects an overall increase of $1.5 million, the net result of the addition of funds to Magellan and the Voyager Interstellar Mission (VIM). This was offset by the Congressional general reduction and the impact of sequestration. The increase for VIM mission is required due to reengineering in preparation for its interstellar space activities. Additional funding for Magellan operations will enable completion of software for radar analysis, data processing and flight command software validation laboratory activities.

BASIS OF FY 1991 ESTIMATE

FY 1991 funding is required for the continued operation and data analysis activities in support of the Pioneer, Voyager, Magellan and Galileo missions as well as for the Ulysses mission which will be launched in October 1990. In support of the Human Exploration Initiative, additional funding has been provided for Mars Observer mission operations. Since Mars Observer is midway through the development cycle, hardware redesigns are not possible. However, major changes in the mission operations phase can still be implemented. Additional funds will extend the basic mission duration from one martian year (687 days) to two and will emphasize high-resolution camera coverage with upgrade image processing capabilities to provide more detailed data on martian surface topography and climate necessary to determine potential landing sites for future Mars missions. Development activities will continue on the Space Flight Operations Center (SFOC) at the Jet Propulsion Laboratory.

BASIS OF FY 1991 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Supporting research and technology.......	46,300	61,300	55,174	65,400
Advanced programs........................	24,700	12,300	10,558	20,100
Mars data analysis.......................	4,700	4,500	4,343	4,000
Halley's comet co-investigations and watch............................	1,200	1,000	535	--
Total.................................	76,900	79,100	70,610	89,500

OBJECTIVES AND STATUS

The research and analysis program consists of four elements to: (1) assure that data and samples returned from flight missions are fully exploited; (2) undertake complementary laboratory and theoretical efforts; (3) define science rationale and develop required technology to undertake future planetary missions; and (4) coordinate an International Halley's Comet Watch program.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, and U.S. scientist participation on foreign missions.

The planetary astronomy activity includes all observations made by ground-based telescopes of solar system bodies, excluding the Sun. Emphasis is on the outermost planets, comets and asteroids. Observations are made at a wide range of wavelengths from ultraviolet to radio. The rate of new discoveries continues to be high, and the data acquired is used both for basic research in support of planetary program objectives and for direct support of specific flight missions. The planetary astronomy funding also provides for the continued operation of the Infrared Telescope Facility in Hawaii. The planetary atmospheres activity includes data analysis, laboratory, and theoretical efforts. The properties of other planetary atmospheres are amenable to measurement with planetary spacecraft and can aid us in better understanding our own weather and climate. Observations of the atmospheres of Venus, Jupiter and Saturn, acquired by Pioneer Venus and Voyager, have laid the basic observational groundwork for major advances in this field.

The planetary geology/geophysics activity is a broadly scoped program that includes the study of surface processes, structure, and history of solid components (including rings) of the solar system and investigation of the interior properties and processes of all solar system bodies, both solid and gaseous. This program emphasizes comparative studies to gain a fundamental understanding of the physical processes and laws which control the development and evolution of all planetary bodies, including the Earth. In this respect, data from the Magellan mission will be of crucial importance.

The planetary materials/geochemistry activity supports an active scientific effort to determine the chemistry, mineral composition, age, physical properties and other characteristics of solid material in the solar system through the study of returned lunar samples and meteorites and through laboratory and theoretical studies of appropriate geochemical problems. Extraterrestrial dust grains, collected for analysis, continue to yield new and otherwise unobtainable information about the solar system, and its early history. This program is coordinated with the lunar sample and meteorite research, which is supported by other agencies, such as the National Science Foundation. The operation of the Lunar Curatorial Facility is also supported by this activity.

The instrument definition activity is directed toward ensuring maximum scientific return from future missions by the definition and development of state-of-the-art scientific instrumentation, which are optimized for such missions.

The objective of the advanced program activity is to provide planning and preparation for the systematic exploration of the solar system on a scientifically and technically sound basis. In response to the agency's Human Exploration Initiative (HEI), the major activities in the advanced programs area are focused on studies of the Lunar Observer program as well as feasibility studies for future Mars missions such as the Mars Network missions and the Mars Rover Sample Return mission to provide the necessary science data technology development required to ultimately support future manned missions to the Moon and Mars. The Mars Data Analysis program continues to support analysis of data obtained by Viking and earlier missions so that we are scientifically prepared for the next phase of Mars exploration. It also supports the establishment of a Planetary Data System (PDS) which will permit the archiving of these and all other data products in a manner which will promote and facilitate their use.

The International Halley's Comet Watch program is part of an international program of cooperative astronomical observations of Halley's Comet. During 1986 and 1987, support was provided to nearly three dozen U.S. co-investigators on the European Space Agency's (ESA) Giotto mission, and to conducting complementary remote sensing investigations carried out with ground based telescopes, aircraft, rockets, and distant spacecraft. Concurrently, an observation program called the International Halley Comet Watch, coordinated by the United States, conducted world-wide scientific observations of the Comet Halley. The objectives of the Watch are: (1) to coordinate scientific observations of Comet Halley through its 1985-1986 apparition; (2) to promote the use of standardized instrumentation and observing techniques; (3) to help ensure that data is properly documented and archived; and (4) to receive and distribute data to participating scientists. These activities will be completed in 1990.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $8.5 million, of which $4.4 million represents a reallocation for inclusion of the Mars Balloon Relay experiment on the Mars Observer spacecraft, and the balance of $4.1 million resulted from the general Congressional reduction.

BASIS OF FY 1991 ESTIMATE

During FY 1991, research efforts will continue in the areas of planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, Mars data analysis, and advanced technology development for future missions. Ground telescope observations will provide data complementary to that obtained from the flight missions, with emphasis on the outermost planets, comets and asteroids. Funding will also support the upgrading and modernization of ground based laboratory instrumentation in order to reduce maintenance costs and down time and to improve capabilities. Initial efforts are directed towards upgrading the Arecibo Radar. A variety of efforts will be pursued to improve our understanding of planetary atmospheres, including laboratory studies of reactions in deep planetary and tenuous cometary atmospheres. Geology/geophysics research will be directed at specific problems in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean, Saturnian and Uranian satellite imaging data acquired by Voyager.

Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1991 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Instrument definition activities will continue to support development of new state-of-the-art instruments for future missions. The Mars Data Analysis Program will support continued analysis of Mars data in preparation for new Mars missions, and for continued development of the Planetary Data System to archive all planetary data for enhanced accessibility for all users.

During FY 1991, research will be initiated to study origins of solar systems to gain an understanding of the origin and evolution of planetary systems, and the paths of various elements and compounds throughout that evolution. The advanced programs funding will be used to aggressively undertake the Lunar Observer mission, as part of the President's Human Exploration Initiative (HEI), by completing spacecraft and mission definition studies and procuring long lead parts to support a 1996 launch opportunity. Feasibility studies will also continue for future Mars missions.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — EARTH SCIENCE AND APPLICATIONS

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Earth observing system	--	--	--	103,000	RD 6-7
Polar platform	(20,400)	(75,300)	(74,000)	132,000	RD 6-7
Earth probes	--	--	--	25,000	RD 6-10
Upper atmosphere research satellite mission	85,200	73,900	64,200	66,000	RD 6-11
Ocean topography experiment	83,000	72,800	80,800	68,000	RD 6-13
Scatterometer	10,600	13,800	13,600	3,700	RD 6-15
Payload and instrument development	46,400	66,500	76,100	49,700	RD 6-17
Mission operations and data analysis	17,600	24,800	23,900	30,400	RD 6-20
Interdisciplinary research	2,200	2,300	8,600	2,400	RD 6-22
Modeling and data analysis	34,100	44,800	38,500	41,300	RD 6-23
Process studies	93,700	107,500	106,200	111,100	RD 6-26
Laser research facilities	7,600	8,200	8,000	8,700	RD 6-29
Airborne science and applications	23,000	19,700	19,399	20,200	RD 6-31
Total	403,400	434,300	439,299	661,500	

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RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

EARTH SCIENCE AND APPLICATIONS

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Distribution of Program Amount by Installation				
Johnson Space Center	25	100	--	--
Marshall Space Flight Center	8,021	6,800	8,562	8,730
Goddard Space Flight Center	182,403	216,500	196,430	412,650
Jet Propulsion Laboratory	134,261	130,400	147,420	148,500
Ames Research Center	30,315	19,700	32,640	32,850
Langley Research Center	19,920	19,800	21,450	23,500
Stennis Space Center	998	500	1,070	1,170
Headquarters	27,457	40,500	31,727	34,100
Total	403,400	434,300	439,299	661,500

OBJECTIVES AND JUSTIFICATION

The ongoing NASA program is making critical near-term contributions to understanding the Earth as an integrated system as well as to environmental issues including global warming and ozone depletion. NASA's base program combines ground-based measurements, laboratory studies, data analysis and model development with a progressive series of satellite missions, including contributing to the scientific research base in ozone monitoring, ocean circulation and atmospheric chemistry. All of these programs are precursors to "Mission to Planet Earth," the first major element of which is the proposed Earth Observing System.

The ability to measure the extent of both the natural and man-induced changes in our global ecosystem is only a preliminary step -- the capability to model and predict the consequences of global change is the ultimate objective. In order to provide a focused and effective mechanism for coordinating and directing federally-funded Earth science research, the U.S. Global Change Research Program (USGCRP) was initiated in early 1989, in which NASA has been a major participant.

NASA programs are both focused and contributory to the stated goal of the USGCRP -- "to gain a predictive understanding of the interactive physical, geological, chemical, biological and social processes that regulate the total Earth system and, hence, establish the scientific basis for national and international policy formulation and decisions relating to natural and human-induced changes in the global environment and their regional impacts." (Our Changing Planet: The FY 1990 Research Plan, Executive Summary).

The specific objectives of the NASA Earth Science and Applications program are to improve our understanding of the processes in the atmosphere, oceans, land surface and interior of the Earth and advance our knowledge of the interactions between these environments. The program provides space observations of parameters involved in these processes and extends the national capabilities to predict environmental phenomena, both short and long term, and their interaction with human activities. Because many of these phenomena are global or regional, they can be most effectively, and sometimes only, observed from space. NASA's programs include scientific research efforts as well as the development of new technology for global and synoptic measurements. NASA's research satellites, Shuttle/Spacelab payload program and Airborne Science and Applications program provide a unique view of the planet Earth, its physical dynamics, and radiative and chemical processes which affect habitability and the solar-terrestrial environment.

A number of significant objectives have been established for the next decade. These include advancing our understanding of the upper atmosphere through the determination of the spatial and temporal distribution of ozone and select nitrogen, hydrogen, and chlorine species in the upper atmosphere and their sources in the lower atmosphere; characterizing the current state of the terrestrial landscape, including the biosphere and the hydrosphere; optimizing the use of space-derived measurements in understanding large scale weather patterns; advancing our knowledge of severe storms and forecasting capabilities, ocean productivity, circulation, and air-sea interactions; and improving the knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction. Studies of the cycling of key biogeochemical elements, interactions between the biosphere and the climate system, the composition and evolution of the Earth's crust and the processes that shape the Earth's crust are essential to our understanding of the global environment.

Effective utilization of remote sensing requires a balanced set of activities including: analytical modeling and simulation; laboratory research of fundamental processes; development of instrumentation, flight of the instruments on the Space Shuttle, research satellites and airborne platforms; collection of in situ ancillary or validation data; and, scientific analysis of data. The approach is to develop a technological capability with a strong scientific base and then collect appropriate data through remote and in situ means, which will address specific program objectives.

The Upper Atmospheric Research Satellite (UARS) will place a set of instruments in Earth orbit which will make comprehensive measurements of the stratosphere, providing data about the Earth's upper atmosphere in spatial and temporal dimensions which are presently unobtainable. Instruments delivered during 1989 will be integrated into the observatory during FY 1990, consistent with the planned launch in 1991.

Design and development activities are being continued on the NASA Scatterometer (NSCAT), which will acquire global ocean data for operational and research use by both military and civil users. Due to cancellation of the Navy Remote Ocean Sensing System (N-ROSS) program, the Scatterometer is currently targeted for launch aboard Japan's ADEOS mission.

Development of the Ocean Topography Experiment (TOPEX) will continue in FY 1990. The objective of TOPEX is to acquire precise observations of the surface topography of the ocean. These data, in conjunction with NSCAT, will enable the first determination of the wind forcing and ocean-current response of the global oceans. Spacecraft development efforts are underway at Fairchild and the Jet Propulsion Laboratory, leading to a 1992 launch.

The Nimbus spacecraft continues to collect unique data which is being used in the study of long-term trends of the Earth's atmosphere, oceans and polar ice, and provides near-real-time data. The Earth Radiation Budget Experiment (ERBE) was successfully launched in 1984 and continues to provide valuable data. NASA is also continuing to support the National Oceanic and Atmospheric Administration (NOAA) by managing the implementation of the polar orbiting NOAA and Geostationary Operational Environmental Satellite (GOES) series on a reimbursable basis.

The objectives of the Shuttle/Spacelab payload development program are to develop, test and evaluate Earth-viewing remote sensing instruments and systems to obtain data necessary to conduct basic research projects as well as provide correlative and developmental feasibility information for major free-flying spacecraft. Current instrument developments include the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS); Active Cavity Radar (ACR); Light Detection and Ranging (LIDAR); and Shuttle Imaging Radar-C (SIR-C). This payload development program will also support the Earth Observing System (EOS) advanced technology development. Proposals submitted in response to the EOS Announcement of Opportunity (AO) are presently under review. Phase B instrument studies are being conducted based on the AO selection results.

The Airborne Science and Applications program has previously provided platforms for observing ozone-depleting reactions in the atmosphere above the Arctic. This effort was a follow-on to the previous expeditions to the Antarctic. In addition, the Airborne program has provided platforms for such diverse studies as soil moisture measurements, atmospheric pollutants detection and vegetation studies. In addition to this continuing research, the FY 1990 program will focus on providing flights for precursor EOS instruments in order to develop and refine techniques for measuring environmental change.

In FY 1991, the Earth Science and Applications Research and Analysis budget has been restructured to reflect the government-wide interdisciplinary approach to the study of the Earth as a system. The EOS will be NASA's primary contribution to the U.S. Global Change Research program, as defined by the Committee on Earth Sciences (CES). The EOS will deliver interdisciplinary, process-oriented data products which will be used for process and modeling-oriented studies.

In the past, the Research and Analysis (R&A) program was organized around traditional Earth science disciplines such as oceans, atmospheric, geology, and land processes. The CES-lead global change effort focuses on broad interdisciplinary studies to begin to understand the Earth as a system. The restructured R&A program presented here has been divided into these CES-defined categories consistent with this interdisciplinary approach.

The previous R&A disciplines of upper atmosphere, oceanic processes, atmospheric dynamics/radiation, land processes, geodynamics, and laser network operations have been restructured into three categories: modeling and data analysis, process studies, and research facilities.

The restructured research program was developed using the FY 1989 ongoing research program as a base. Each task within each discipline was scrutinized to determine to which interdisciplinary research category it belonged. Beyond FY 1990, a sustained level of effort will be maintained to provided focused research in global change.

- The Modeling and Data Analysis program will focus on developing predictive models for global change and analyzing data sets to determine mechanisms at work in the global environment. The program will focus on two major areas--physical climate and hydrological systems, and biogeochemistry and geophysics.

- The Process Studies program will utilize a variety of techniques to develop an understanding of the processes at work in the global environment and to determine interdependencies which may impact global change management strategies. The program will utilize existing data sets and will conduct field experiments which will enable researchers to better understand global environmental dynamics. Process studies concentrates on four major interdisciplinary categories--radiation dynamics and hydrology; ecosystem dynamics and biogeochemical cycles; atmospheric chemistry; and solid Earth science.

- The Research Facilities program will focus on the laser research facility which supports studies and experiments in solid Earth science and provides support to flight programs such as TOPEX/Poseidon, which require precise Earth pointing information.

BASIS FOR FY 1991 FUNDING REQUIREMENT

EARTH OBSERVING SYSTEM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Earth observing system development	--	--	--	103,000
Polar platform development..............	(20,400)*	(75,300)*	(74,000)*	132,000
Total...............................	--	--	--	235,000

* Development funding for the Polar Platform prior to 1991 is included in Space Station Freedom budget.

OBJECTIVES AND STATUS

NASA's FY 1991 budget proposes a major new start for the key element of the U.S. Global Change Research program--initiation of the "Mission to Planet Earth" and its major component, the Earth Observing System (EOS). The primary objective of the EOS is to document global change and to observe regional-to-global scale processes. Utilizing a diverse but balanced suite of instruments, two series of three polar orbiting platforms (6 platforms in total), instruments attached to the Space Station Freedom, and U.S. instruments on European and Japanese polar platforms, the EOS will document global change over a 15-year period to provide long-term, consistent data sets for use in modeling global change processes. Each platform will have a five-year design life. Each series will have a different, but complementary focus: EOS-A will focus largely on land mass observations; EOS-B on oceans and atmospheres. This process and modeling research effort will provide the basis for establishing predictive global change models which may be used by policy makers and scientists in formulating strategies to manage human impacts on global processes such as the greenhouse effect, ozone depletion and deforestation of the rain forests.

The EOS program will provide comprehensive measurements of the physical climate of the Earth through measurements of the radiation budget from two polar orbiting platforms at different times of day and night, as well as measurements from the Space Station Freedom over the tropics. The atmosphere will be characterized by temperature, winds and moisture from the ground to the mesopause. The combination of sensors on EOS will provide multiparameter data to study precipitation processes, snow and ice processes, glacier mass balance and air-sea interactions. Passive microwave sensors, combined with cloud imagers, will provide simultaneous measurements of cloud-top temperature and rain rate. This will improve our understanding of precipitation formation within storms. The processes by which the oceans and the atmosphere exchange moisture, trace gases, heat and momentum will be studied using boundary layer measurements.

EOS will monitor many parameters that are indicators of the state of the environment, such as the spatial and temporal distribution of tropospheric and stratospheric gases (e.g., carbon dioxide, carbon monoxide, methane, ozone, oxides of nitrogen and sulfur compounds). In addition, interdisciplinary theoretical investigations will be conducted to utilize EOS and complementary data sets to study such phenomena as ecosystem distributions and conditions; biogeochemical fluxes at the ocean-atmosphere and land-atmosphere interfaces; fluxes of carbon and nutrients within terrestrial, freshwater and oceanic systems; and atmospheric composition.

Utilizing up to 30 closely-coupled, complementary instruments, the EOS will be designed to observe regional and global scale processes such as El Nino, desertification, ozone levels and ocean circulation. The EOS will use both passive and active sensors in the visible, infrared and microwave spectrums. Global coverage will be provided every two days at 1 kilometer resolution using radiometers, spectrometers, radar and lidar. The first launch in the series (EOS-A) is planned for FY 1998.

The budgetary entry shown for Polar Platform represents a transfer from the Space Station Freedom program to the Office of Space Science and Applications (OSSA). Beginning in FY 1991, OSSA will have budget and management responsibility for the Polar Platform, with project management residing with the EOS program. This management transfer was based on the determination that the EOS-driven capabilities of the platform could be achieved in a more cost-effective manner by designing the platform in conjunction with the EOS. There is a corresponding decrease in the Space Station budget.

The project's scientific data processing components consist of a Central Data Handling Facility, a Data Archival and Distribution System, and an Information Management Center. These three elements comprise the EOS Data Information System (EOSDIS). The initial phase of the EOS data information facility construction to house the EOSDIS at the Goddard Space Flight Center (GSFC) is included in the Construction of Facilities appropriation request.

Due to the size and complexity of this mission, an augmentation to the civil service staffing levels has been requested in the Research and Program Management appropriation budget for FY 1991. The augmentation amounts to 145 full-time equivalents (FTE's) in FY 1991, 291 FTE's in FY 1992 and 350 FTE's in FY 1993. One hundred and twenty-five of the FY 1991 augmentation will be at GSFC, which has the overall responsibility for mission management of the project. An additional 20 FTE's are required by NASA Headquarters for total program management and oversight responsibility. The full range of necessary skills will be included under this augmentation, from project and program management, to critical systems engineering skills, and including resource analysis, computer systems analysis, mission operations planning, etc.

BASIS OF FY 1991 ESTIMATES

FY 1991 funding is required to initiate development and long lead procurement activities for the EOS-A series of observatories and to continue technology development activities on the EOS-B series of instruments. Phase B studies for all Announcement of Opportunity selected instruments have begun and are scheduled for completion during FY 1990.

The National Research Council has been asked to conduct a review of the 1991 U.S. Global Change Research Program (USGCRP) plan of which EOS is a significant part. In particular, the review will consider several specific issues regarding EOS, including environmental parameters to be measured, the requirement for simultaneity of data collection, and the optimal configuration of the EOS platform and instruments. Results of the study are expected to be completed prior to the initiation of the development phase of the mission in FY 1991.

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BASIS FOR FY 1991 FUNDING REQUIREMENT

EARTH PROBES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Earth probes............................	--	--	--	25,000

OBJECTIVES AND STATUS

A second component of Mission to Planet Earth is also proposed as a FY 1991 new initiative--the Earth Probes program. Earth Probes will provide an explorer-class program to address specific, highly focused problems in Earth science. The program will provide the programmatic flexibility to take advantage of unique opportunities presented by international cooperative efforts and technical innovation and will serve to maintain and increase Earth science research vitality.

Planned Earth Probes include the Total Ozone Mapping Spectrometer (TOMS) free-flyer to be launched on a Scout-class vehicle, and the NASA Scatterometer (NSCAT) on the Japanese ADEOS satellite. Other missions include the Tropical Rainfall Mapping Mission (TRMM) and the Proteus ocean productivity experiment which are critical to the maintenance of long-term, time-series data sets.

The Earth Probes program complements the Earth Observing System program by providing the ability to investigate processes best observed from special orbits, such as TRMM's requirement for a low altitude, low inclination orbit for diurnal cycle coverage, and special sensor requirements such as magnetically clean spacecraft for gravitational investigations.

In FY 1990, $10 million was appropriated by Congress to begin development of TOMS instruments. This funding is carried in FY 1990 under Earth Sciences Payload and Instrument Development.

BASIS OF FY 1991 ESTIMATE

FY 1991 funding is required to continue development of the NASA Scatterometer for the ADEOS mission and begin development on the TOMS free-flyer spacecraft. Scatterometer funding is required to meet the ADEOS 1993 instrument delivery schedule and to modify the instrument for the unique ADEOS configuration. Funding will augment the current NSCAT budget, which was reduced in previous budgets to a "build and store" mode following cancellation of its original host vehicle, the Navy's N-ROSS satellite. TOMS funding is required to begin development of the satellite for a launch in 1993. Phase B studies are nearing completion for TRMM and definition continues for the follow-on missions.

BASIS OF FY 1991 FUNDING REQUIREMENT

UPPER ATMOSPHERE RESEARCH SATELLITE PROGRAM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Spacecraft	44,800	20,000	15,200	11,000
Experiments	40,400	53,900	49,000	55,000
Total	85,200	73,900	64,200	66,000
STS Operations	(26,300)	(34,700)	(56,100)	(58,500)

OBJECTIVES AND STATUS

The Upper Atmosphere Research Satellite (UARS) program is the next step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere aimed at improving basic scientific understanding. This mission, scheduled for a Shuttle launch in 1991, is essential for understanding the key radiative, chemical and dynamical processes which couple together to control the composition and structure of the stratosphere. The UARS mission will provide the first integrated global measurements of: ozone concentration; chemical species that affect ozone; energy inputs; temperature; and winds in the stratosphere and mesosphere. These measurements will complement the measurements of ozone and of atmospheric parameters affecting ozone that were made on Nimbus and SAGE. The UARS program is a critical element in overall stratospheric research and monitoring efforts; it will provide the first full data set on stratospheric composition and dynamics which will be required when difficult environmental policy decisions must be made in the future regarding production of chlorofluorocarbons. The UARS mission will also contribute to the assessment of the impact of stratospheric changes on our climate and will provide the data needed for a full understanding of the stratosphere. These understandings are essential for subsequent design and implementation of a long-term stratospheric monitoring activity.

The ten experiments include infrared and microwave limb sounders which require advances in cryogenics, solid-state devices and microwave antennas beyond earlier capabilities. The instrument deliveries and integration are underway. A Solar Backscatter Ultraviolet (SBUV) instrument will be modified to fly on the Shuttle during the UARS mission and to provide correlative data. In addition, development of the central ground data handling facility, which will permit near-real time interactive utilization of data by the nineteen design and theoretical investigator teams, is underway.

CHANGES FROM FY 1990 BUDGET ESTIMATE

A reduction of $8.0 million was made to provide funds for the TOPEX mission, which required additional funding to overcome technical and schedule problems experienced by its mission contractor. The remaining $1.7 million decrease is the result of the general Congressional reduction and the FY 1990 sequestration. While some increased risk will be assumed due to these reductions, no flight delay is anticipated.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funds are required for continuing integration and calibration activities of the ten UARS instruments and to support spacecraft delivery to KSC and the launch of UARS on the Space Shuttle. FY 1991 funding is also required to complete integration of the ground data handling facility including hardware and software verification activities prior to launch. The ground data handling facility will enable a higher level of interaction among experimenters and theoreticians than has existed with past programs. Implementation of this concept requires that the system be developed on a timely parallel path with the flight hardware so that individual experiment data processing subsystems, including algorithms and the interactive data base, provide maximum interaction and effectiveness in the design and development phase of the program and are fully verified at launch time.

BASIS OF FY 1991 FUNDING REQUIREMENT

OCEAN TOPOGRAPHY EXPERIMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Ocean topography experiment (TOPEX)......	83,000	72,800	80,800	68,000

OBJECTIVES AND STATUS

The goal of the Ocean Topography Experiment (TOPEX) is to utilize satellite radar altimetry to measure the surface topography of the global oceans over a period of three years with sufficient accuracy and precision to significantly enhance our understanding of the oceans' general circulation and its mesoscale variability. The capability of satellite altimetry to address this goal was demonstrated in 1978 by NASA's Seasat program. Such information is needed to better understand how the atmosphere drives the circulation of the oceans, how the oceans in turn influence the atmosphere and ultimately, the role of the oceans in climate.

NASA and the French Space Agency (CNES) are collaborating on TOPEX in order to more fully exploit the scientific value of the data. In exchange for this scientific collaboration and the flight of a French altimeter and tracking system, CNES will launch TOPEX in June 1992 on an Ariane launch vehicle. TOPEX is also being planned in concert with the World Ocean Circulation Experiment (WOCE), a major international oceanographic field program being planned under the auspices of the World Climate Research Program (WCRP). WOCE will combine satellite observations from TOPEX with traditional *in situ* observations to enable the first comprehensive determination of the three-dimensional current structure of the global oceans. When further combined with ocean surface winds from the NASA Scatterometer (NSCAT), unique measurements of the oceans' driving force (winds) and the resulting ocean response (topography) will have been obtained.

During FY 1990, the satellite contract will continue in the development phase, and integration and test of the spacecraft and sensors will begin. The joint NASA/CNES science team will continue its effort to develop and verify algorithms to produce consistent data products for the science teams.

CHANGES FROM FY 1990 BUDGET ESTIMATE

An additional $8.0 million was added to the TOPEX program from the UARS program to maintain critical schedules leading to launch in June 1992.

BASIS OF FY 1991 ESTIMATE

In 1991, TOPEX will continue with full-scale spacecraft system integration and test. Spacecraft delivery will occur in late 1991 for integration to the Arianne 4 launch vehicle. CNES and Ariannespace have signed contracts to provide launch services for a June 1992 launch.

BASIS OF FY 1991 FUNDING REQUIREMENT

SCATTEROMETER

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Scatterometer.............................	10,600	13,800	13,600	3,700

OBJECTIVES AND STATUS

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology. In addition to providing wind field data, Scatterometer data will permit the first global study of the influence of winds on ocean circulation, provide data on the effects of the oceans on the atmosphere, and provide improved marine forecasting (winds and waves).

The feasibility of using the Scatterometer technique from space to accurately measure winds was demonstrated by Seasat in 1978. Definition studies conducted by NASA during FY 1983 and early FY 1984 resulted in the determination that the performance requirements as stated jointly by the research community and the Navy could be satisfied by utilizing system design concepts similar to those used on the Seasat Scatterometer. The major improvements include the addition of two antennas for improved wind direction determination and the addition of digital filtering to compensate for Earth rotational effects.

The Scatterometer was planned to fly on the Navy Remote Ocean Sensing System (N-ROSS) satellite in 1992. The N-ROSS program was cancelled in 1988 due to financial constraints. Scatterometer has been selected as the primary science instrument on the Japanese ADEOS mission. Launch is scheduled for February 1995, with instrument delivery to the Japanese in 1993.

During FY 1990, the Traveling Wave Tube Amplifier (TWTA) contract is scheduled to be completed and the development of the other flight hardware items will be continued. Delivery of the second computer system for the ground data system will occur in FY 1990. Other FY 1990 activities include the design of the antenna deployment system required by ADEOS (previously supplied as part of the N-ROSS bus) as well as continued subsystem modifications necessary due to the unique characteristics of the Japanese spacecraft.

CHANGES FROM FY 1990 BUDGET ESTIMATE

A minor reduction was made to Scatterometer as a result of the general Congressional reduction.

BASIS OF FY 1991 ESTIMATE

Planned activities in FY 1991 include the continuation of flight hardware development leading to the beginning of flight unit integration and testing at the end of fiscal year 1991, the completion of software requirements definition, the initiation of detailed software design, both for the ground data and flight systems; conducting the Preliminary Design Review for the mission operation system; and confirmation of the science team. The FY 1990 budget reflected a program funding plan consistent with the reduced scope resulting from the N-ROSS being cancelled. With the Scatterometer's selection for flight on the ADEOS, the required augmentation for Scatterometer is requested under the Earth Probes initiative.

BASIS OF FY 1991 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Atmospheric payloads....................	6,600	10,100	20,100	10,700
Earth sensing payloads..................	25,300	32,200	32,200	31,700
EOS ATD.................................	14,500	24,200	23,800	7,300
Total................................	46,400	66,500	76,100	49,700

OBJECTIVES AND STATUS

The Space Transportation System offers the unique opportunity for short-duration flights of instruments. The Earth Science and Applications program has incorporated this capability into the Shuttle/Spacelab payload development activities in these important aspects: early test, checkout and design of remote sensing instruments for long duration free-flying missions; and short-term atmospheric and environmental data gathering for basic research and analysis where long-term observations are impractical. Instrument development activities support a wide range of instrumentation, from airborne to international flights of opportunity.

The objective of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) experiment is to make detailed measurements of gaseous constituents (e.g., hydrogen chloride, water, ammonia, methane) in the Earth's atmosphere by using the technique of infrared absorption spectroscopy. The data will help determine the compositional structure of the upper atmosphere, including the ozone layer and its spatial variability on a global scale. The instrument was launched in 1985 on Spacelab-3 and data analysis continues. It will be reflown on the ATLAS (formerly EOM) series. The science results from the first flight of ATMOS were of exceptional value, and the basic capability of ATMOS to measure very low concentrations of trace species in the Earth's atmosphere was clearly demonstrated. In FY 1987, ATMOS commenced a ground observation program at Table Mountain Observatory which will continue until the instrument is readied for shipment to KSC for the Atlas-1 Spacelab mission.

The Measurement of Air Pollution from Satellites (MAPS) experiment is a gas-filter correlation radiometer designed to measure the levels of troposphere carbon monoxide and the extent of interhemispheric mass transport in the lower atmosphere. The instrument was flown successfully on two Shuttle flights, and data

analysis continues. It is planned for three more STS flights, to provide the first observations of the global seasonal variation of carbon monoxide in the Earth's atmosphere. Reflight of MAPS is also planned on the SRL series.

The Active Cavity Radiometer-1 (ACR-1) is designed to aid in the study of the Earth's climate and the physical behavior of the Sun. Reflights of ACR-1 on the ATLAS series are planned. Other experiments have also been selected for reflight, including some instruments which were flown on the Shuttle orbital flight tests, and Spacelabs-1 and -2.

A Total Ozone Mapping Spectrometer (TOMS) instrument is being prepared for flight on the Soviet Meteor-3 spacecraft in 1991. FY 1990 activities will continue this refurbishment of a previously-existing TOMS engineering model consistent with its scheduled flight.

Components of the Shuttle Imaging Radar-B (SIR-B) will be used in building the next generation Imaging Radar instrument, SIR-C. The SIR-C will use multi-polarized, dual frequency sensor technology. SIR-C is in the development phase; system requirements review, antenna preliminary design review and system preliminary design review are complete. In October 1987, NASA signed a Memorandum of Understanding with the Federal Republic of Germany agreeing to joint missions of SIR-C with an x-band imaging radar to be provided by a joint German/Italian project (X-SAR). Preparations continue for commercialization of the Large Format Camera (LFC).

EOS advanced technology development activities in FY 1990 will focus on the completion of Phase B activities for the EOS-A instruments selected in the Announcement of Opportunity. The final selection of EOS-A instruments is scheduled for completion in September 1990. In addition, EOS-B instruments will continue in Phase B in support of a scheduled instrument selection in September 1991. Other activities include the completion of Phase B definition of the EOS Data Information System.

Advanced spectrometer technology development activities include fundamental research in remote sensing involving airborne and spaceborne imaging spectrometer instruments. The imaging spectrometer and linear array solid-state sensor research focuses on the development of such features as inherent geometric and spectral registration and programmable high spatial and spectral resolution. The critical technology development and supporting research on the High Resolution Imaging Spectrometer (HIRIS) and the linear array focal plan will continue.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The increase results from the Congressionally directed addition of $10.0 million to begin development of additional Total Ozone Mapping Spectrometer Instruments (TOMS), partially offset by a decrease resulting from the general Congressional reduction. This funding will allow continuation of the TOMS instrument for the Soviet flight in 1991, as well as initiation of a new competitive procurement of 4 TOMS instruments planned for the 1993 Scout-launched free-flyer and other missions of opportunity.

BASIS OF FY 1991 ESTIMATE

Refurbishment of a TOMS engineering model for flight on a Soviet spacecraft in 1991 will be completed. This mission and the development of TOMS instruments for future flights will ensure a constant flow of data on the density and spatial distribution of ozone in the atmosphere.

FY 1991 funds will also be used to support the Measurement of Air Pollution from Satellites (MAPS) science team activities including data reduction, refurbishment for reflight and upgrading of the ground service equipment. The FY 1991 funding for ATMOS is required to support the ground observation program as well as continued science team activities, data processing and analysis, and limited refurbishment. FY 1991 funding is also required to continue the Active Cavity Radiometer (ACR) data processing, science team activities, and refurbishment for reflight on future Shuttle ATLAS flights, and development of a free-flyer version of ACR.

Development activities will continue on the international (U.S. and France) Light Detection and Ranging (LIDAR) airborne instrumentation following completion of critical design reviews in preparation for the integration, ground test and first flight in FY 1991 of this multi-phase user program. In this program, both NASA and France are supplying science knowledge and hardware to demonstrate first-time detail measurements of the atmosphere to aid in forecasting. FY 1991 funding is required for continued development of SIR-C technology, and for advanced spectrometer activities including the development of the Shuttle Imaging Spectrometer Experiment.

Preliminary definition of the advanced instrumentation and data facilities associated with the proposed Earth Observing System will be continued in FY 1991. The EOS instruments are the intended payload on the polar platforms and attached payloads. Activities will focus on completion of Phase B activities for EOS-B instrument definition to support final instrument selection in September 1991, along with related system engineering and payload accommodation studies.

BASIS OF FY 1990 FUNDING REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Mission operations and data analysis.....	17,600	24,800	23,900	30,400

OBJECTIVES AND STATUS

The objective of the extended mission operations program is to provide for the operations, data processing, validation and data analysis of missions which have completed basic operations funded by approved project support.

Launched in 1978, the Nimbus-7 spacecraft continues to provide significant quantities of both atmosphere and solid Earth global data for multi-discipline investigations and applications. These include atmospheric dynamics and chemistry resulting in global ozone measurements that are helping to understand the complicated heat exchanges of the atmosphere-ocean system, and, for the first time, global ocean data and sea ice concentration as well as properties of both polar caps. NASA supplies this unique sea ice concentration data in near real-time to the joint U.S. Navy-NOAA Ice Center. The ocean color measurements provide the only data on open ocean and coastal area chlorophyll concentration which relates to abundance of phytoplankton, the basic element of the ocean food chain. Current studies of complete ocean basins are expanding the understanding of global productivity. Nimbus-7 operations and data reduction/validation activities will continue in FY 1991 to support the strong demand for data.

The Correlative Measurements program serves to compare and/or correct data gathered by Nimbus and other NOAA meteorological satellites. Reprocessing of data from the Shuttle Solar Backscatter Ultraviolet Spectrometer (SSBUV) will continue in FY 1990, with two scheduled flights in the Shuttle payload bay, as a complement to ongoing Nimbus-7 operations.

The Earth Radiation Budget Experiment (ERBE) and its component Stratospheric Aerosol and Gas Experiment (SAGE) measure temporal variations in the Earth's radiation budget and ozone gases, in order to gain basic insight into the causes of climatic fluctuations. The ERBE/SAGE project consists of instruments launched in 1984 on the NASA Earth Radiation Budget Satellite (ERBS), and on two National Oceanic and Atmospheric Administration (NOAA) satellites in 1984 and 1985.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The reduction is due to the general Congressional reduction and the impact of the FY 1990 sequestration. Some data analysis activities will be deferred as a result.

BASIS OF FY 1991 ESTIMATE

Operation of the Nimbus satellite and processing of the collected data will be continued as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA meteorological satellite. Nimbus continues to produce extremely valuable data on ozone concentrations which will be used to estimate the occurrence of natural and man-made variations in ozone density, sea surface temperatures, aerosol measurements, and ocean productivity. Correlative ground truth activities will also be continued in FY 1991; these in situ observations are needed to verify the quality of remote observations and improve our ability to interpret them. The SSBUV instrument is scheduled for one Shuttle flight in FY 1991, and will support verification of measurements obtained from the Upper Atmosphere Research Satellite after its launch in the fall of 1991. In an agreement with Japan, data from the Japanese Earth Resources Satellite (JERS) will be available to U.S. investigators following its 1991 launch, with FY 1991 funds supporting the study and utilization of this data.

In addition, FY 1991 funding is required for operating the ERBS spacecraft, data processing and analysis from the total three-instrument system, and from the SAGE-II instrument on ERBS.

BASIS OF FY 1991 FUNDING REQUIREMENT

INTERDISCIPLINARY RESEARCH AND ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Interdisciplinary research and analysis..	2,200	2,300	8,600	2,400

OBJECTIVES AND STATUS

Interdisciplinary research activities need to be conducted to quantitatively characterize the Earth's chemical, physical, and biological processes on the land, along with the interactions between the land, the oceans, and the atmosphere, which are of particular importance in assessing the impact of these pheonmena on global, physical, and biogeochemical processes. Such research is essential to investigating and assessing long-term physical, chemical, and biological trends and changes in the Earth's environment. Included in the program activities are joint efforts from a variety of disciplines, including atmospheric science, climatology, biological sciences, geochemistry, and oceanography.

CHANGES FROM FY 1990 BUDGET ESTIMATE

As directed by Congress, $9.0 million has been added for climate studies and university consortia research, offset by the general Congressional reduction and the impact of sequestration. Climate funding will augment NASA's current climate modeling program, including those activities underway at the Goddard Institute for Space Studies. The university funding is planned to initiate the Earth Science Information (ESI) research project at the University of Michigan. This program will enhance access and use of Earth science and related information by the scientific and policy-making community in pursuit of global change issues.

BASIS OF FY 1991 ESTIMATE

In FY 1991, interdisciplinary studies will be continued with emphasis on integrating discipline-specific research activities of oceanic processes, atmospheric dynamics and radiation, upper atmosphere/troposphere chemistry, and land processes into a unified program which will help increase our understanding of critical global processes. Emphasis will be placed on specific pilot studies such as those understanding the biogeochemical processes controlling the concentration of atmospheric methane, characterizing changes in properties of the land surface and their effect on climate, and understanding the role of the oceans in the global carbon cycle.

BASIS OF FY 1991 FUNDING REQUIREMENT

MODELING AND DATA ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Physical climate and hydrologic systems modeling and data analysis.............	21,800	26,800	23,800	26,000
Biogeochemistry and geophysics modeling and data analysis.............	12,300	18,000	14,700	15,300
Total................................	34,100	44,800	38,500	41,300

OBJECTIVES AND STATUS

The Biogeochemistry and Geophysics program has as its objectives the development of global change models dealing with all aspects of the biology, chemistry, geology, and geophysics of the Earth system and with the exploitation of satellite data in the monitoring of global change as well as the study of the mechanisms which are at work in the global environment.

The research and analysis activities within the Physical Climate and Hydrologic System program provide a focus for contributing to an improved understanding of the fully-integrated geophysical climate system, its interactions and predictability, through the development and multi-disciplinary exploration of global satellite observations of the Earth, numerical modeling, climate impact assessments, and sensitivity studies. The two principle components of the program are in the areas of climate modeling research and climate data analysis.

The objectives of the climate modeling research program are to develop and improve coupled physical atmosphere/ocean global general circulation models which assimilate and optimize the use of satellite-derived data sets for understanding climate interactions, forcing and feedback, to help guide the design of the global observing system, and to improve the capability for reliable climate diagnosis and forecasting. The program builds on the broad foundation established over the past decade of research on geophysical modeling conducted under the NASA Atmospheric Dynamics and Radiation and Ocean Processes programs.

The objectives of the Climate Data Analysis Program are to assemble a long-term global record of climate parameters, with an emphasis on satellite remote sensing, for specifying and analyzing the state of the climate system and its variability. These include the full range of geophysical variables which describe the structure and composition of the atmosphere, oceans, land surfaces, and cryosphere, as well as their boundaries, interfaces, and external forcings. The program builds on earlier accomplishments achieved through such diverse research initiatives as the International Satellite Cloud Climatology Project (ISCCP), the Earth Radiation and Budget Experiment (ERBE), the Global Atmospheric Research Program (GARP) and current activities in support of the Tropical Oceans Global Atmosphere Program (TOGA) and the World Ocean Circulation Experiment (WOCE). These programs are elements of the World Climate Research Program (WCRP), sponsored by the World Meteorological Organization and the International Council of Scientific Unions. Such international relationships are strongly encouraged by the U.S. Global Change Research Program plan.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease is the result of the general Congressional reduction and the impact of the FY 1990 sequestration. Research and analysis activities will be correspondingly decreased, although climate studies have been Congressionally augmented under Interdisciplinary Research and Analysis, thereby mitigating the full impact.

BASIS OF FY 1991 ESTIMATE

In FY 1991, particular emphasis will be placed on readying stratospheric photochemical models for use in analysis of the anticipated data return from the Upper Atmosphere Research Satellite. Extension of the analyses of global observations of total ozone, ocean phytoplankton distribution, and the phenology of the land vegetation index will also occur in FY 1991. The availability of standard data products to the research community will be increased through the production of optical disks containing data sets. Modeling of the biosphere will largely emphasize the provision of biospheric modules for incorporation of more physically-oriented circulation models of the atmosphere and oceans. Satellite data will continue to be used to analyze the structure of the Earth gravity and magnetic fields, and modeling efforts will proceed in parallel to relate these observations to the processes at work in the Earth's interior.

Fiscal Year 1991 funding is required in the area of climate modeling for improving current atmospheric and physical oceanographic models leading to the development and validation of coupled atmosphere/ocean/cryosphere/land surface global general circulation models; for the development of techniques for model assimilation of asynoptic satellite data; for improving parameterizations of model sub-grid scale phenomena such as the planetary boundary layers, cumulus convection, cloud-radiation and ice-albedo feedbacks; and for assessments of model performance through sensitivity studies and

model-to-model intercomparisons. The issues relating to four-dimensional data assimilation are particularly crucial to the NASA climate modeling program. Over the next two decades a vast quantity of remotely sensed and in situ data will become available for climate studies. To gain maximum benefit from these large heterogeneous data sets, it is essential that they be quality controlled, interpreted into directly measurable quantities, and then synthesized into a model-generated time evaluation of the atmosphere and ocean. The development of techniques for implementing these steps will be given high priority in view of NASA's unique role in space observations of the Earth.

In the area of Climate Data Analysis, FY 1991 funding is required for continuing the processing of satellite-derived climate data sets important to the understanding of contemporary climate issues such as the potential for greenhouse gas-induced global warming. Of utmost importance are reliable global records of Earth radiation budget quantities such as reflected solar radiation (albedo), outgoing longwave radiation, clouds, aerosols and surface properties. These data, when combined with solar insulation global temperature records will provide new insight into the factors controlling the storage and transport of energy within the Earth's climate system and its loss to space. The physical oceanography component of the program will continue to build on two major elements: an ocean circulation component with radar altimetry as the primary source of data and an air/sea interaction component based on radar scatterometry and passive microwave measurements. The common denominator linking these diverse efforts is the timely provision of reliable documented global geophysical data records to the broad scientific community for use in understanding and eventually predicting global change. Funding will also support the further developments and exploitation of the NASA pilot data systems (NASA Climate Data System, NASA Ocean Data System, and Alaska SAR facility) as they evolve into the EOS Data Information System in the mid 1990's. These data systems have served as a valuable source of NASA environmental data by providing easy access by the scientific community.

BASIS OF FY 1991 FUNDING REQUIREMENT

PROCESS STUDIES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Radiation dynamics and hydrology.........	27,500	31,700	31,400	33,400
Ecosystem dynamics and biogeochemical cycles..................................	16,400	20,800	20,500	21,000
Atmospheric chemistry....................	24,900	27,400	27,000	29,300
Solid earth science......................	24,900	27,600	27,300	27,400
Total....................................	93,700	107,500	106,200	111,100

OBJECTIVES AND STATUS

The research and analysis activities within the Radiation, Dynamics and Hydrologic Processes program combine a core effort of theoretical, laboratory, and field investigations essential to understanding the basic geophysical processes and their interactions which control climate. The two principle components of the program are in the areas of radiation and dynamic processes research and hydrologic processes research.

The objectives of the radiation and dynamics research program are to improve our understanding of the basic physical processes by which the atmospheric system stores and transports energy. Of all the exchange processes, radiation energy has a special role in climate because the energy balance of the climate system as a whole is determined by a balance between absorbed solar radiation and emitted thermal radiation. Gradients in the net radiation drive the circulations of the atmosphere and oceans. Special emphasis is given to the processes responsible for cloud-radiation feedback. The first International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE), which builds on the foundation established earlier under the NASA Atmospheric Dynamics and Radiation research program, is a central focus for the program. FIRE is an integrated research program whose objectives are: to expand our basic knowledge of how clouds and cloud systems interact with their environment and climate; to identify and simulate the physical and chemical processes instrumental in the evolution of large-scale cloud systems; to quantify and improve the capabilities of current models for simulating large-scale cloud systems and the radiative properties of these systems and improve cloudiness and radiation parameterizations used in global models; and to assess and improve the reliability of current cloud/radiation monitoring systems from space and from the ground.

The objectives of the hydrologic processes research program are to improve our understanding of the physical processes which govern the hydrological cycle and its impact on the atmosphere and oceans. The prediction of global change in the geosphere and biosphere will be one of the most important problems in environmental sciences in the 21st century. Estimation of the distribution and transport of carbon, nitrogen, sulfur, etc., cannot be attained without knowledge of the atmospheric circulation and water cycle on regional and global scales. The availability of water is also a major factor affecting the distribution of the biomass and biological productivity. The biomass and land cover in turn, play a role in controlling the absorption of solar radiation, evapotranspiration, and turbulent heat transfer.

The ecosystem dynamics and biogeochemical cycles program conducts research on the function of global ecosystems and the interactions of the Earth's biota with the atmosphere and hydrosphere. Particular emphasis is placed on land-atmosphere interactions, both physical and chemical; carbon cycling, especially in the oceans; and the biophysics of remote sensing of ecosystems.

The goal of the ecosystem dynamics program element is to achieve an improved understanding of the role of the biosphere and the biologically-linked components of the hydrologic cycle in processes of global significance. The goal of the biogeochemical cycles program element is to achieve an improved understanding of the sources, sinks, fluxes, trends and interactions involving the biogeochemical constituents within the Earth system, with an emphasis on their major biospheric reservoirs, including oceanic, freshwater, and terrestrial systems.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease is the result of general Congressional reduction and the FY 1990 sequestration. The impact of the reduction will be only minor deferrals in planned research activities.

BASIS OF FY 1991 ESTIMATE

Fiscal Year 1991 funding is required in the area of radiation and dynamics research to continue studies of the processes associated with cloud-radiation feedback, ocean circulation and heat flux. A second phase of FIRE cirrus cloud layer research will be implemented, consisting of an integrated modeling and measurements program. The experimental components of FIRE are contained in Intensive Field Observations (IFO). The main IFO is scheduled for the November-December 1991 time frame at the site of the National Weather Service wind profile network near Wichita, Kansas. A concentration of surface and aircraft in situ and remote sensors is planned including lidar, wind profiles and interferometers. Fiscal Year 1991 funding is also needed to complete the Global Backscatter Experiment (GLOBE). Aerosol data from GLOBE will be used in the system design of the Laser Atmospheric Wind Sounder (LAWS) planned for the Earth Observing System.

In the area of hydrologic processes, FY 1991 funding will support the scientific and engineering studies required for defining the Tropical Rainfall Measurement Mission (TRMM) and for planning a comprehensive data validation program. Additional efforts will support the planning for the international Global Energy and Water Cycle (GEWEX) initiative of the World Climate Research Program. GEWEX will observe and model the global hydrological cycle, with the goal of predicting variations of global and regional hydrologic processes and water resources, and their response to environmental change.

BASIS OF FY 1991 FUNDING REQUIREMENT

RESEARCH FACILITIES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Laser research facilities................	7,600	8,200	8,000	8,700

OBJECTIVES AND STATUS

The objective of the Laser Research program is to measure the movement and deformation of the tectonic plates of the Earth. Laser ranging to satellites and the moon, microwave interferometry using astronomical radio sources and transmissions from the Global Positioning Satellite System (GPS) are used to determine precise position locations.

Measurements over the past years have provided experimental determination of the velocities of several of the major tectonic plates. Measurements of regional deformation across the San Andreas Fault continue to indicate a relative movement of the Pacific and North American Plate of about 6 cm per year. In addition, measurements indicate that about 4 cm of this movement is occurring in Southern California. Measurements of polar motion and changes in the length of day have been correlated, to a high degree, with variations in the angular momentum and the inertial balance of the Earth's atmosphere due to high altitude winds. The Earth's rotation was found to have slowed by five milliseconds due to the El Nino effect. Models of the Earth's gravity field, derived from Laser Geodynamics Satellite (LAGEOS-1) data have provided the first evidence of gravity field variations. These variations are believed to be caused by continued relaxation of the crust following the last ice age and have confirmed estimates of the viscosity of the Earth's mantle layer.

The United States and a consortium of eight European and Middle East countries continue measurements of crustal deformation in Greece, Turkey, and Italy. A mobile Laser Ranging Station operated by the Federal Republic of Germany joins similar U.S. stations in deformation studies in the U.S.

Development of instrumentation and techniques for use of the Department of Defense GPS system for rapid crustal motion measurements has continued. The geodetic techniques developed by NASA for measurement of polar motion and Earth rotation have been adopted by the International Union of Geodesy and Geophysics as the basis of the new International Earth Rotation Service. Within the U.S., NOAA and the U.S. Naval Observatory have adopted Very Long Baseline Interferometry as the basis for the National Earth Orientation Service.

Emphasis in FY 1991 will be on investigations analyzing existing data sets acquired from a series of Multisensor Airborne Campaigns (MAC) conducted in previous years. Analysis of the Howland Forest MAC, Oregon Transect Ecosystem Research MAC, Hydrology MAC and the First ISLSCP Field Experiment will continue. Remotely sensed data spanning the electromagnetic spectrum will be combined with extensive ground data acquisitions to elucidate basic ecosystem and biogeochemical cycling processes and to develop the biophysical understanding to apply remotely sensed data without such intensive ground validation in the future. A second intensive field campaign for the Howland Forest MAC will be conducted in the spring of 1991.

CHANGES TO FY 1990 BUDGET ESTIMATE

The minor decrease is the result of the general Congressional reduction.

BASIS OF FY 1991 ESTIMATE

In FY 1991, measurements of plate motion between North America and Europe will be continued in cooperation with countries in Europe, the Middle East, Far East, South and Central America. Measurements of the motions of the Pacific Plate will be continued in cooperation with Japan and China. Regional crustal deformation measurements in western North America will continue in cooperation with NOAA, Canada and Mexico. The Caribbean studies will be continued and include more sites along the plate boundary and on the plate itself.

LAGEOS-1 and other satellites will continue to be used for studies of plate motion. NASA laser systems in the U.S., Pacific, South America, and Australia will be operated in cooperation with laser systems in 12 other countries. The LAGEOS-2, a joint mission with Italy, is presently under development by Italy and will be launched by the Space Shuttle in 1991.

BASIS OF FY 1991 FUNDING REQUIREMENT

AIRBORNE SCIENCE AND APPLICATIONS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Airborne science and applications........	23,000	19,700	19,399	20,200

OBJECTIVES AND STATUS

The Airborne Science and Applications effort covers operation of two ER-2's, a C-130, and a DC-8 in order to support Earth-sensing and atmospheric research. The DC-8 was acquired to replace the CV-990 research facility, "Galileo II", which was destroyed in 1985. The replacement DC-8 has undergone required upgrades and modifications and carried out operations in the Arctic in 1989 as part of the Ozone Hole campaign. Acquisition of a second ER-2, to replace the aging U-2C's was completed in FY 1989. These aircraft support other major segments of the Space Science and Applications program dealing with the Earth, the oceans, and the atmosphere. They may serve as test beds for newly developed instrumentation and allow demonstration of new sensor techniques before their flight on satellites or on Shuttle/Spacelab missions. Data obtained from these aircraft are used to refine analytical algorithms, and to develop ground data handling techniques. For example, the ER-2's acquire stratospheric air samples and conduct in-situ measurements at altitude ranges above the capability of more conventional aircraft and below those of orbiting satellites. This capability is important in gaining an understanding of stratospheric transport mechanisms.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The minor decrease is the result of the Congressional general reduction.

BASIS OF FY 1991 ESTIMATE

Requested FY 1991 funding will allow operation of the DC-8, two ER-2's, and the C-130. Operation of these aircraft will allow continuation of such projects as the collection and analysis of stratospheric air samples, testing of newly-developed instrumentation, the demonstration of new sensor concepts, the investigation of the Ozone Hole phenomena, and participation in numerous other field experiments such as the International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE).

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

MATERIALS PROCESSING IN SPACE

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and analysis	13,600	13,000	12,566	13,700	RD 7-3
Materials experiment operations	56,400	74,600	81,429	79,900	RD 7-4
Commercial microgravity R&D enhancements	5,600	5,100	5,020	3,700	RD 7-6
Total	75,600	92,700	99,015	97,300	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	1,295	3,500	1,375	1,366
Marshall Space Flight Center	26,624	29,700	38,081	33,909
Ames Research Center	100	200	--	--
Lewis Research Center	19,770	24,300	26,727	30,058
Langley Research Center	3,275	4,200	2,005	2,970
Jet Propulsion Laboratory	18,623	19,500	27,029	22,948
Headquarters	5,913	11,300	3,798	6,049
Total	75,600	92,700	99,015	97,300

PROGRAM OBJECTIVES AND JUSTIFICATION

The Microgravity Science and Applications program uses the unique attributes of the space environment to conduct research in three primary areas: 1) Fundamental Science, which includes the study of the behavior of fluids, transport phenomena, condensed matter physics and combustion science; 2) Materials Science, which includes electronic and photonic material, metals, alloys, glasses and ceramics; and 3) Biotechnology, which focuses on micromolecular crystal growth and cell science. Goals of the program include developing a comprehensive research program in these primary areas, as well as developing a structured understanding of gravity-dependent physical phenomena. This understanding will provide the basis of a reliable predictive capability for processing operations and technology issues in both Earth and non-Earth environments. In FY 1991, ground-based research and payload development will support these program goals.

During FY 1991, ground-based research will support definition studies for flight experiment candidates in areas such as containerless processing, solidification and crystal growth, fluids and combustion research and processing of biological materials. Research will be conducted in drop-tubes, towers and aircraft.

The Microgravity Material Experiment Operations program provides a range of experimental capabilities. The program currently supports a wide variety of hardware development, from unique flight experiments necessary to conduct fundamental research to modular, multi-user research facilities that will be the cornerstone of microgravity science and applications research on Space Station Freedom. Experiments will be flown on Shuttle and Spacelab, as well as any promising commercial space facility.

BASIS OF FY 1991 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS (MATERIALS PROCESSING)

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Research and Analysis (ground-based).....	13,600	13,000	12,566	13,700

OBJECTIVES AND STATUS

The research and analysis activity provides the scientific foundation for all current and future projects. Ground-based research leads to space investigations with potential for future applications. This activity also supports technology development for future ground and space capabilities, and applications activities leading toward privately-funded space enterprises. Most research projects are initiated as a result of proposals from the scientific community which are extensively reviewed by peer groups prior to selection.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease in FY 1990 is due to the Congressional general reduction as well as the impact of the sequestration.

BASIS OF FY 1991 ESTIMATE

Ground-based research and analysis will be continued in FY 1991 in the areas of fundamental science, materials science and biotechnology. Research will be conducted to define the role of gravity-driven influences in generic processing methods. Effort will continue at the Microgravity Materials Science Lab at the Lewis Research Center.

BASIS OF FY 1991 FUNDING REQUIREMENT

MATERIALS EXPERIMENT OPERATIONS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Materials experiment operations..........	56,400	74,600	81,429	79,900

OBJECTIVES AND STATUS

The Materials Experiment Operations program provides experiments for a wide range of opportunities. NASA currently supports the development of STS middeck, Spacelab and cargo-bay experiments. This policy maximizes the effective use of the STS by matching an experiment with the hardware best suited to meet its scientific and technical requirements. Preparations are underway to use Space Station Freedom as a major element for conducting microgravity research, consistent with the strategy for orderly evolution of microgravity experiments from ground-based research to the Shuttle, and finally to Space Station. During FY 1990 and FY 1991, Space Station hardware definition will continue, as well as equipment development and delivery for the first United States Microgravity Laboratory (USML-1) Spacelab mission. Increased emphasis is being applied to NASA's Physics and Chemistry Experiments (PACE) program, which uses microgravity research to challenge and improve existing scientific theory about the fundamental nature of matter. As other nations increase their ability to exploit the characteristics of near-Earth space, the "cutting edge" experiments generated by the PACE program will play an increasingly important role in assuring continued U.S. leadership in microgravity research.

CHANGES IN THE FY 1990 BUDGET

An increase of $8 million is due to unanticipated complexity in meeting science performance requirements for the crystal growth furnace, an integral part of the USML-1 mission. The increase is partially offset by the general Congressional reduction and the impact of the sequestration.

BASIS OF FY 1991 ESTIMATE

FY 1991 funding is required to continue basic and applied research activities as well as payload development effort, using STS middeck, Spacelab and cargo-bay experiments leading to several flights over the next few years. Investigations are planned in fluid dynamics, glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will continue on PACE experiments as well as several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metals and alloys, and containerless processing.

BASIS OF FY 1991 FUNDING REQUIREMENT

COMMERCIAL MICROGRAVITY R&D ENHANCEMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Commercial microgravity R&D Enhancements.	5,600	5,100	5,020	3,700

OBJECTIVES AND STATUS

The Commercial Microgravity R&D Enhancements budget supports several projects formerly managed by NASA's Office of Commercial Programs (OCP). The program funds the cost of modifying existing microgravity research hardware to accommodate members of the commercial user community and consolidates funding within the Office of Space Science and Applications (OSSA) for joint OSSA/OCP multiuser facilities.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease in FY 1990 is due to the general Congressional reduction and the impact of sequestration.

BASIS OF FY 1991 ESTIMATE

The FY 1991 Commercial Microgravity R&D Enhancements budget supports continued development of the Crystal Growth Furnace for flight on the United States Microgravity Laboratory series, and will provide funding needed to accommodate commercial users on existing flight hardware and ground-based microgravity research facilities.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — COMMUNICATIONS

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Advanced communications technology satellite (ACTS)	74,600	--	59,975	34,000	RD 8-3
Advanced communications research	11,886	12,700	12,275	12,500	RD 8-4
Search and rescue	1,350	1,300	1,280	1,400	RD 8-6
Radio science and support studies	2,900	3,100	2,996	3,300	RD 8-8
Communications data analysis	1,464	1,500	1,449	1,600	RD 8-9
Total	92,200	18,600	77,975	52,800	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Goddard Space Flight Center	3,792	3,914	3,170	3,497
Jet Propulsion Laboratory	5,829	4,642	4,184	4,603
Lewis Research Center	79,468	6,547	64,748	39,780
Johnson Space Center	100	110	--	--
Headquarters	3,011	3,387	5,873	4,920
Total	92,200	18,600	77,975	52,800

OBJECTIVES AND STATUS

The ACTS program will develop advanced technologies and use these technologies in a joint experiments program in conjunction with U.S. industry to prove the utility of on-board switching (the baseband processor) and simultaneous communications transmissions to different terrestrial locations through an intricate multibeam antenna.

Advanced communications research continues to provide the development of subsystem component technology required by NASA, other government agencies, and U.S. industry for advanced communications satellite systems. Special emphasis is being given to technologies with high potential for improving spectrum utilization, satellite switching, and inter-satellite link technologies, since these technologies are the key to future growth of the communication satellite and terminal markets. An example of the technologies under study is optical space communications, which will extensively improve space communications capabilities. The mobile communications program has completed development of enabling technologies and is now ensuring the use of the technologies by the private sector.

The Search and Rescue program is an international cooperative program that has demonstrated the use of satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system, in which Norway, the United Kingdom, Bulgaria, Sweden, Denmark, Switzerland, Brazil and India also participate.

The Radio Science and Support Studies program provides the technical basis to support U.S. and NASA interests in international and domestic communications regulatory forums. Propagation studies and measurements are performed in order to understand and account for the effects of propagation in the design and specification of space communications systems. Studies to enable new satellite applications are conducted.

Communications Data Analysis assists other federal agencies and public sector organizations in the development of experimental satellite communications for emergency, disaster and public service applications. The main areas of work are preparation for optical intersatellite communications and operation of the Applications Technology Satellite (ATS-3), launched in 1967.

BASIS OF FY 1991 FUNDING REQUIREMENT

ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Advanced communications technology satellite (ACTS)	74,600	--	59,975	34,000
STS operations	(13,400)	(--)	(14,000)	(58,400)
Upper stage	(18,700)	(--)	(9,300)	(13,200)

OBJECTIVES AND STATUS

The Advanced Communications Technology Satellite (ACTS) program is planned to maintain U.S. leadership in the communications satellite market by the development and flight verification of advanced technologies that will enhance the capability of communications satellites.

The U.S. user community, representing the private sector organizations and other government agencies, will develop and execute experiments that will test and evaluate the ACTS technologies under various applications scenarios. The ACTS key technologies include high effective isotropic radiated power (EIRP); fast-hopping multiple beam antenna; on-board intermediate frequency and baseband switching; and Ka-band components; and dynamic rain fade compensation techniques. ACTS is planned for an STS/TOS launch in May 1992.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The change from the FY 1990 budget estimate is due to the Congressional reinstatement of ACTS in the NASA budget.

BASIS OF FY 1991 ESTIMATE

During FY 1991, integration and test of the ACTS flight and ground systems will continue. Environmental test of the flight system will be completed in FY 1991 and final preparations for shipment to the launch site in early FY 1992 will be initiated.

BASIS OF FY 1991 FUNDING REQUIREMENT

ADVANCED COMMUNICATIONS RESEARCH

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Advanced communications research.........	11,886	12,700	12,275	12,500

OBJECTIVES AND STATUS

The advanced communications research program emphasizes the development of high-risk technology required to maintain U.S. preeminence in the international satellite communications market, to enable new and innovative public services, and to meet the communications needs of NASA and of other government agencies. This program focuses on the "interconnectivity technologies" of on-board switching, inter-satellite links, and antennas, as well as advanced optical and radio frequency technologies. Advanced studies are performed to determine the future satellite communications needs of the country and to define the technology required to meet those needs. The technology is developed and tested through an advanced proof-of-concept (POC) program. The POC devices and components are then integrated into a multiple terminal, satellite communications network in a laboratory where they undergo comprehensive evaluation.

The mobile satellite communications effort, in cooperation with U.S. industry, Canada, and other government agencies, will help implement a first generation commercial system. A consortium of commercial firms has been formed to introduce mobile satellite communications in the U.S. NASA's current role in mobile satellite communications is to expedite the transfer of the NASA-developed technologies to the private sector and to stimulate the commercial development of mobile satellite communications through a barter agreement. Funding for the mobile satellite launch is included in the expendable launch vehicles budget. The future NASA research role, when the mobile satellite communications system is operational, will be aimed at testing power, bandwidth, and orbital-slot efficient ground segment technology. In addition, NASA plans to use the mobile communications systems to test data networking techniques and to support public service communications requirements.

In FY 1990, the satellite communications applications research program has been initiated. The program objectives are to advance satellite-based communications technology systems that show promise for use by the space communications industry. The program will be based on the results of a competitive NASA Research Announcements that NASA plans to issue on an periodic basis.

Work is continuing on advanced communications technologies. The optical space communications terminal, employing low-power lasers, will permit communications between satellites and ground terminals, satellites and low-Earth-orbiting spacecraft, such as the Space Shuttle or Space Station Freedom, and between satellites and other geosynchronous orbiting satellites, such as the Tracking and Data Relay Satellite (TDRS). The preliminary design of a prototype optical communications system has been completed. Technology development is also underway in the area of monolithic microwave integrated circuits (MMIC), which have significant potential for applications in multi-port spacecraft matrix switches, low noise receivers, and multibeam antenna arrays and beam-forming networks. NASA has held a number of discussions with industry to define key areas of communications technology that should be undertaken by NASA to benefit U.S. industry in the 1990's and beyond.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The change from the FY 1990 budget estimate is due to the general Congressional reduction and the impact of sequestration.

BASIS OF FY 1991 ESTIMATE

The Research and Analysis program will continue to support development of the hardware necessary for future space communications satellite systems, encompassing both optical and radio communications technologies. In FY 1991, NASA will be working more closely with industry than at any time in the past to identify future communications needs and fund promising technology developments through the NASA Research Announcement process.

BASIS OF FY 1991 FUNDING REQUIREMENT

SEARCH AND RESCUE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Search and rescue........................	1,350	1,300	1,280	1,400

OBJECTIVES AND STATUS

The NASA role and budget for the international Search and Rescue program are limited to research and development that apply NASA technologies to advanced equipment design and techniques. For the U.S., NOAA has responsibility for all aspects of operational Search and Rescue, while the Coast Guard and the Air Force perform the rescues. The international Search and Rescue partners are Canada, France, the Soviet Union, Norway, the United Kingdom, Bulgaria, Sweden, Denmark, Switzerland, Brazil and India. After FY 1989, the NASA budget contains no funding for Search and Rescue operations.

The Search and Rescue program, developed by NASA and international partners, has demonstrated the feasibility of using satellites to improve detection and location of general aviation aircraft and marine vessels during emergencies.

Beginning in FY 1989, as part of the Search and Rescue program, NASA has begun to undertake more public service endeavors that capitalize on space communications technologies and processes. As part of the post-development phase of the NASA Search and Rescue program, we have begun to prepare for the application of NASA's skills to a wide range of emergencies. The Armenian telemedicine spacebridge work, completed in 1989, will serve as a prototype for the types of services NASA can offer. NASA in cooperation with the U.S. space communications industry established a video communications link between Armenia and the U.S. shortly after the area was devastated by an earthquake. Over that link, U.S. physicians and medical personnel, working under the NASA Space Life Sciences program, collaborated on medical cases.

CHANGE FROM FY 1990 BUDGET ESTIMATE

The change from the FY 1990 Budget Estimate is due to the general Congressional reduction.

BASIS OF FY 1991 ESTIMATE

Funding in FY 1991 will continue the NASA-unique research and development role in Search and Rescue, including the next generation satellite-borne Search and Rescue equipment, future system planning, and advanced techniques. Consistent with inter-agency plans and commitments, the NASA budget contains no funding for Search and Rescue operations after FY 1989. As necessary, the FY 1991 budget will also support public service communications activities, like the Armenian telemedicine spacebridge.

BASIS OF FY 1991 FUNDING REQUIREMENT

RADIO SCIENCE AND SUPPORT STUDIES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Radio science and support studies........	2,900	3,100	2,996	3,300

OBJECTIVES AND STATUS

Radio science and support studies provide the technical basis for regulatory and policy development to assure the orderly growth of existing and new satellite services. Unique analytical tools are developed and used to solve problems of inter- and intra-satellite/terrestrial system interference. Emphasis is placed on orbit and spectrum utilization studies, which include the development of frequency and orbit sharing techniques and strategies, design standards, and the determination of the effect of propagation phenomena and man-made noise on performance, design, and efficient use of the geostationary satellite orbit and the radio spectrum.

During FY 1990, the radio science and support studies program will conduct propagation studies to help minimize radio signal atmospheric interference problems in space communications as well as other advanced studies to enhance U.S. utilization of space by communications satellites.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The change from the FY 1990 Budget Estimate is due to the general Congressional reduction and the impact of sequestration.

BASIS OF FY 1991 ESTIMATE

Studies will continue to make efficient use of the radio frequency spectrum and geostationary-satellite orbit. It will provide the technical basis for standards development and regulatory decisions for space services at the national and international levels. Propagation studies and measurements will be carried out to fill the voids in data needed for design of new satellite applications for fixed communications, mobile communications, sound broadcasting, and high definition television broadcasting. Studies will be performed to enable new satellite applications.

BASIS OF FY 1991 FUNDING REQUIREMENT

COMMUNICATIONS DATA ANALYSIS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Communications data analysis.............	1,464	1,500	1,449	1,600

OBJECTIVES AND STATUS

The objectives of Communications Data Analysis are to support and to document a wide range of user experiments and demonstrations of the application of satellite communications. Past experiments on experimental satellites, such as the Applications Technology Satellite (ATS) series and the Communications Technology Satellite (CTS), have successfully provided users with the experience necessary to make informed decisions regarding the satellite communications functions. NASA's role to stimulate use of unique space facilities has led to wider application of commercial satellites that better meet the needs of potential users.

The main emphasis of Communications Data Analysis in FY 1990 will be experiment definition for the optical communications program. Optical communications in space will employ very low power lasers to transmit information, much like current terrestrial fiber optics techniques. The advantages of optical space communications will be high data rates that will be needed for future Earth orbital intersatellite links, deep space-to-Earth orbital links, and Earth orbital-to-ground links.

Communications data analysis will continue to support the Applications Technology Satellite (ATS) satellite, ATS-3, used by several government agencies and universities.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The change from the FY 1990 Budget Estimate is due to the general Congressional reduction and the sequestration.

BASIS OF FY 1991 ESTIMATE

Experiment definition and data analysis for optical communications analysis will continue in FY 1991, as will communications data analysis support of ATS-3.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS **INFORMATION SYSTEMS**

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Information systems......................	19,900	34,100	28,217	36,800
Distribution of Program Amount by Installation				
Goddard Space Flight Center..............	12,875	18,736	16,070	21,492
Jet Propulsion Laboratory................	3,655	3,463	3,500	4,850
Ames Research Center.....................	1,600	6,254	4,162	4,832
Stennis Space Center.....................	95	--	--	--
Marshall Space Flight Center.............	--	3,700	1,750	2,500
Headquarters.............................	1,675	1,947	2,735	3,126
Total..................................	19,900	34,100	28,217	36,800

OBJECTIVES AND STATUS

The Information Systems program is divided into four major discipline areas; scientific computing, science data management and archiving, science networking, and information systems research and analysis. In addition, the important function of conveying facts about NASA's information and data management systems is undertaken as part of program management responsibility. The Information Systems program provides the advanced data systems to support the nation's space science and applications flight and research projects.

Scientific computing provides for the operation of the super-computing resources of the NASA Space and Earth Sciences Computing Center (NSESCC) in support of modeling and simulation efforts. Also included here is the definition and development of capabilities necessary for efficient use of the Office of Space Science and Applications (OSSA) research and computing assets.

Science data management and archiving provides the OSSA research community with reliable systems to archive and distribute data. The National Space Science Data Center (NSSDC) archives and distributes data acquired from spaceflight investigations. OSSA researchers benefit from automated retrieval of archived data, a master directory for the location of distributed data sets by researchers, and delivery of data on advanced media as requested by users. Services now under development include catalog inter-operability for common searches across distributed databases and utilization of data exchange standards to facilitate automated assimilation of data by user applications.

The main area of science networking is the NASA Science Internet. NASA Science Internet is a computer networking service developed for NASA's space science and applications community to enable NASA researchers worldwide to connect to databases, to computational resources, and also to other scientists for interactive collaboration. A main objective is to provide transparent and reliable networking connectivity to support OSSA's flight missions and discipline programs, including joint projects with other agencies and international organizations.

Information systems research and analysis emphasizes the application of advanced computer and information systems technology to improve the effectiveness and efficiency of science data management, analysis, and visualization.

During FY 1990, the NSESCC supercomputer will begin an upgrade program to a capability of nearly 10 times the power of the current equipment. The science data management discipline will begin to process the data returning from missions launched recently. The NASA master directory will be completed and made fully operational. Development of tools to help implement international data standards will be initiated. The NASA Science Internet network will begin the first year of operations as part of the information systems program.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The change from the FY 1990 Budget Estimate is due to the general Congressional reductions and the impact of the FY 1990 sequestration. Due to this reduction, use of the NASA Science Internet network will be constrained and improvements planned in the data management area will be deferred to FY 1991.

BASIS OF FY 1991 ESTIMATE

The Information Systems program will continue emphasis on the application of computer science technologies to support the work of the NASA science disciplines. Funding is included for continued operation of the NSESCC and NSSDC. The Information Systems program will continue to develop common software to support ongoing research in the space and Earth sciences. Science data networking needs will be met with the NASA Science Internet, allowing more users access to the network consistent with the recently-launched and near term science investigations. FY 1991 funding will also allow previously deferred data system improvements to occur in preparation for the expected wealth of science return in the 1990's.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Technology utilization....................	16,500	22,700	23,700	24,400	RD 10-1
Commercial use of space..................	28,200	38,300	32,832	76,600	RD 11-1
Total..................................	44,700	61,000	56,532	101,000	

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF COMMERCIAL PROGRAMS

TECHNOLOGY UTILIZATION

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Civil systems	1,817	3,000	7,200	8,000	RD 10-4
Product development	600	2,400	1,000	1,000	RD 10-4
Acquisition, dissemination and network operations	4,446	5,800	5,800	5,700	RD 10-4
Program development, evaluation and coordination	2,278	1,700	3,700	3,700	RD 10-5
Technology applications	5,159	6,800	6,000	6,000	RD 10-5
Industrial outreach	2,200	3,000	--	--	RD 10-5
Total	16,500	22,700	23,700	24,400	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	2,164	885	415	510
Kennedy Space Center	255	682	510	600
Marshall Space Flight Center	304	704	340	260
Stennis Space Center	770	1,231	940	1,110
Goddard Space Flight Center	824	1,720	940	1,365
Jet Propulsion Laboratory	1,035	1,135	1,050	1,000
Ames Research Center	386	600	340	475
Langley Research Center	799	1,359	640	698
Lewis Research Center	469	575	440	704
Headquarters	9,494	13,809	18,085	17,678
Total	16,500	22,700	23,700	24,400

OFFICE OF COMMERCIAL PROGRAMS | **TECHNOLOGY UTILIZATION**

OBJECTIVES AND JUSTIFICATION

The NASA Technology Utilization program is designed to strengthen the national economy and industrial productivity through the transfer and application of aerospace technology resulting from NASA's Research and Development (R&D) programs. To accomplish this objective, NASA has established and operates a number of technology transfer mechanisms to provide timely access of useful technologies to the private and public sectors of the economy. Almost every part of U.S. industry is affected by the technology transfer process, especially in such areas as automation, electronics, materials, and productivity. In the public sector, medicine, rehabilitation, transportation and safety are areas in which aerospace technologies have been especially beneficial. The specific objectives of the program are:

- To accelerate and facilitate the application of new technology into the commercial sector, thus shortening the time between the generation of advanced aeronautics and space technologies and their effective use in the economy;

- To encourage multiple secondary uses of NASA technology in industry, education, and government, where a wide spectrum of technological problems and needs exist; and

- To develop applications of NASA's aerospace technology, including its unique facilities, to priority nonaerospace needs of the Nation.

The Technology Utilization program promotes the transfer of technology developed in NASA's R&D programs to the public and private sectors of the U.S. economy. A network of Industrial Applications Centers (IAC's), Technology Counselors, and NASA installation Technology Utilization Officers form the core of the Agency's technology transfer efforts. Technologies developed for the Nation's aerospace program are reused or reengineered to provide new products and processes in the areas of transportation, energy, medicine, public safety, and consumer goods. The goals of the program are to broaden and accelerate the technology transfer process to realize additional dividends on the national investment in aerospace research and to ensure that the U.S. maintains its competitive position in the international marketplace.

Activities in FY 1990 will include:

- Sustaining the capability of the Technology Utilization Offices at the NASA Field Centers, and maintaining the Technology Utilization Network System (TUNS) which links the NASA Technology Utilization (TU) field center offices, the NASA Software Repository, Computer Software Management and Information Center (COSMIC), the Scientific and Technical Information Facility and the Industrial Applications Centers (IAC) together to provide a timely distribution of new technologies.

- Promoting awareness of NASA's Technology Utilization program and resources available to the public and private sectors through a broad array of program materials, seminars and conferences.

- Maintaining the nationwide technology transfer network to continue the development of cooperative efforts with the Federal Laboratory Consortium (FLC), state-sponsored business and technical assistance center, and Small Business Development Centers. These linkages enable the Technology Utilization program to keep pace with growing industrial demand for information and technology transfer services.

- Continuing implementation of the AdaNET program, designed to transfer existing and emerging Ada software and other software engineering technology from the federal government to the private sector through mechanisms such as information sharing and repository services and networks. The National Aeronautics and Space Administration, the Department of Defense, and the Department of Commerce are participating in this program.

CHANGES FROM FY 1990 BUDGET ESTIMATE

Civil systems has increased from $3.0 million to $7.2 million to accommodate funding for Congressionally mandated programs. These funds have been provided from a $2.0 million transfer from the Office of Space Science and Applications (OSSA) and an additional $2.0 million transfer from the Office of Space Station. Due to past success in industrial outreach the focus on this task will be lessened and carried out within the existing Centers for the Commercial Development of Space (CCDS) and IAC programs. Therefore, the Industrial Outreach program has been reduced from $3.0 million to zero. Program development has been increased to support TU work at the Scientific and Technical Information Facility and to meet our commitments to the FLC. Product development has been decreased resulting in a more limited publication effort in the area of new technology identification and reporting.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Civil systems...........................	1,817	3,000	7,200	8,000

In FY 1991 Civil Systems will complete funding of AdaNET, a program to transfer existing and emerging Ada software and other software engineering technology from the federal government to the private sector through mechanisms such as information sharing and repository services and networks. The National Aeronautics and Space Administration, the Department of Defense, and the Department of Commerce are participating in this program.

Additionally, NASA plans to complete Phase I implementation of the NTTC to serve as a national focal point to aid U.S. industry in locating appropriate Federal technologies and technology transfer services to accelerate the flow of advanced technological resources into use and application in American industry. It is expected that the NTTC development processes will extend over the next 5 years, and will become fully integrated with existing technology transfer mechanisms and sources of useful technology resulting from Federally-sponsored R&D programs.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Product development......................	600	2,400	1,000	1,000

New technology identification and reporting will continue in FY 1991. These resources will provide for evaluation and packaging of these technologies for publication thereby stimulating industrial interest and participation in NASA's Technology Utilization program.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Acquisition, dissemination and network operations....................	4,446	5,800	5,800	5,700

In FY 1991, NASA plans to continue maintenance of its IAC network and its installations to provide for identification of NASA technical capabilities and expertise. This capability and expertise is necessary for matching and cross-correlating NASA technology with industry needs specified by NASA IAC. Moreover, IAC participation and integration with establishment of the NTTC will be further developed in FY 1991.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Program development, evaluation and coordination	2,278	1,700	3,700	3,700

Long range plans for NASA Technology Utilization (TU) will focus efforts on assessing potential participants in U.S. industry, preparing information guidelines to support cooperative relationships throughout the NASA technology transfer network, as well as satisfying anticipated demand for TU publications and responses to program inquiries are among the many management planning and support requirements.

Technology applications	5,159	6,800	6,000	6,000

In FY 1991, a broadening of application team responsibilities is anticipated to assist NASA IAC in bringing together industrial client problems with existing aerospace technologies leading to project definition and industry-driven cooperative projects. This effort will result in increased tangible and meaningful applications of aerospace technology in the private sector, thus enhancing the productivity and competitive posture of U.S. industry.

Industrial outreach	2,200	3,000	--	--

This outreach effort will be conducted by the CCDS (under their basic grant charter) for Commercial Use of Space and by the IAC's (under their basic contract effort), for Technology Utilization.

OFFICE OF COMMERCIAL PROGRAMS

COMMERCIAL USE OF SPACE

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Commercial applications and enhancements.	22,700	31,800	26,332	38,900	RD 11-4
Commercial development support...........	3,100	3,900	3,900	4,200	RD 11-4
Commercial transportation................	2,400	2,600	2,600	33,500	RD 11-5
Total..................................	28,200	38,300	32,832	76,600	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center.....................	1,572	1,700	1,250	3,700
Kennedy Space Center.....................	977	661	750	2,980
Marshall Space Flight Center.............	1,236	1,900	900	1,710
Stennis Space Center.....................	2,711	5,500	3,750	6,000
Goddard Space Flight Center..............	250	300	500	1,050
Ames Research Center.....................	728	550	400	750
Langley Research Center..................	--	1,095	--	--
Lewis Research Center....................	252	1,000	--	--
Headquarters.............................	20,474	25,594	25,282	60,410
Total..................................	28,200	38,300	32,832	76,600

<u>OFFICE OF COMMERCIAL PROGRAMS</u> <u>COMMERCIAL USE OF SPACE</u>

OBJECTIVES AND JUSTIFICATION

The goal of the Commercial Use of Space program is to support a national focus which develops opportunities for the expansion of U.S. private sector investment and involvement in civil space activities. The specific objectives of the program are to:

- Foster close working relations with the private sector and academia to encourage investment in space technology and the use of the *in situ* attributes of space--vacuum, microgravity, temperature and radiation for commercial purposes.

- Facilitate private sector space activities through improved access to available NASA resources and the development of new high technology space ventures and markets.

- Encourage increased private sector investment in the commercial use of space independent of NASA funding.

- Implement and support commercial space policy NASA-wide.

NASA's goal of expanding opportunities for U.S. private sector investment and involvement in civil space and space-related activities is pursued through a variety of interrelated programs. Through cooperative agreements such as Joint Endeavor Agreements (JEA's) and through the agency's support to the Centers for the Commercial Development of Space (CCDS), the amount of space-related research conducted by the private sector, the number and type of NASA and private sector facilities available for space use, and the private sector awareness of the opportunity to use NASA's terrestrial and space-based facilities for commercial research will be increased.

Resources will be made available to obtain flight support experimentation hardware required by industrial researchers. This may include across-the-bay carriers, such as Materials Science Laboratories, as well as middeck augmentation racks or derivatives thereof, and the possible leasing of private sector hardware

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developed to exploit commercial research and development in space. The use of ground-based research facilities, aircraft, and sounding rockets for commercial experimentation will provide limited access to the microgravity environment for appropriate commercial experiments.

In order to maintain momentum in Commercial Use of Space activities and to encourage an increase in private sector investment in space, NASA will continue to develop methods to facilitate private sector agreements and commitments to develop commercial opportunities in space. The development of agreements for the use of the Shuttle external tanks and private sector use of U.S. launch facilities reflect this effort. The use of Space Systems Development Agreements (SSDA's) will continue.

CHANGES FROM FY 1990 BUDGET ESTIMATE

As a result of 1990 Congressional actions, Commercial Applications and Enhancements has been reduced $5.5 million (which includes a $2.5 million transfer to Construction of Facilities for the Wake Shield). This reduction will result in deferral of existing programs, including planned work in space flight support for the Centers for the Commercial Development of Space, and remote sensing.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Commercial applications and enhancements.	22,700	31,800	26,332	38,900

In FY 1991 NASA will continue the Centers for the Commercial Development of Space (CCDS). Sixteen CCDS's have been established in such diverse areas as space propulsion, biotechnology, materials processing, and space remote sensing. The CCDS's are a focus for the commercialization of space. This is accomplished through space-related research conducted by the private sector and NASA, and the enhancement of private sector awareness of the availability of NASA's terrestrial and space-based facilities for potential commercial research and exploration. Funding will be increased to provide support to flight projects focused to respond to industry identified requirements. Continued development of space-oriented, ground-based facilities and equipment will expand the technical research data base which enables the private sector to make economic decisions to commit to space research and production. Through intra-NASA coordination, the private sector, academia, state and local centers, the Department of Defense and other government agencies, guidance will be developed and provided for commercial microgravity research and development enhancements program.

Funding is provided for the analytical and physical integration required for Space Shuttle payloads flown under Joint Endeavor Agreements (JEA's), and CCDS Flight Agreements. Direct funding is provided for reimbursable optional services which are deferred under some Space Systems Development Agreement (SSDA's); funds are also provided for CCDS payload optional services. NASA's current SSDA's are with Spacehab, Geostar, and Space Industries Partnership.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Commercial development support...........	3,100	3,900	3,900	4,200

Rapidly changing economic, commercial and technical circumstances continue to require analysis to provide private sector direction and feedback to the NASA program. In FY 1991, additional emphasis will be placed on our strategic planning, financial analysis, international competitiveness, and technical program support to implement an effective Commercial Space Development program, and to assist in the development of agency commercial space policy.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Commercial transportation	2,400	2,600	2,600	33,500

In an effort to provide CCDS payloads with timely and varied access to space, and to further support commercial space transportation ventures, a major new initiative will commence in FY 1991. Current NASA flight support to commercial payloads has been limited to Space Transportation System middeck and cargo bay opportunities, and more recently has included CCDS sounding rocket flights. This new initiative has three major components. First, our existing sounding rocket program will be augmented to provide larger sounding rockets which in turn lengthen payload exposure to the microgravity environment. Second, we will develop small orbital ELV program which will provide the long duration microgravity exposure required for some commercial payloads (e.g., protein crystal growth). Finally, to allow us to elevate commercial payloads to primary payload status and meet commercial requirements expeditiously, we will pursue the lease of a commercially-provided payload module which will provide pressurized man-tended payload capability in the cargo bay.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY FOR AERONAUTICS AND SPACE RESEARCH AND TECHNOLOGY

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Aeronautics research and technology......	398,200	462,800	449,756	512,000	RD 12-1
Transatmospheric research and technology.	69,400	127,000	59,027	119,000	RD 13-1
Space research and technology............	285,900	338,100	285,871	495,900	RD 14-1
Exploration mission studies..............	(14,900)	(20,000)	(15,000)	(37,000)	RD 15-1
Total................................	753,500	927,900	794,654	1,126,900	

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RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

AERONAUTICAL RESEARCH AND TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and technology base	309,563	335,700	326,122	353,400	RD 12-5
Systems technology programs	88,637	127,100	123,634	158,600	RD 12-26
Total	398,200	462,800	449,756	512,000	

Distribution of Program Amount By Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Marshall Space Flight Center	1,800	3,900	2,100	2,000
Jet Propulsion Laboratory	300	300	800	900
Goddard Space Flight Center	200	200	600	600
Ames Research Center	151,500	169,200	165,100	187,800
Langley Research Center	141,500	165,000	159,900	183,000
Lewis Research Center	94,100	114,200	111,000	125,000
Headquarters	8,800	10,000	10,256	12,700
Total	398,200	462,800	449,756	512,000

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — AERONAUTICAL RESEARCH AND TECHNOLOGY

OBJECTIVES AND JUSTIFICATION

The goal of the NASA program is to conduct aeronautical research and develop technology to strengthen U.S. leadership in civil and military aviation. This goal is supported by five comprehensive program objectives: (1) emphasize emerging technologies with potential for major advances in capacity and performance; (2) maintain NASA's laboratory strength by repairing and modernizing critical national facilities, providing advanced scientific computational capabilities and enhancing staff technical excellence; (3) ensure timely transfer of research results to the U.S. aeronautics community through reports, conferences, workshops and cooperative research programs with industry; (4) ensure strong university involvement to broaden the nation's base of technical expertise and innovation; and (5) provide technical expertise and facility support to the Department of Defense (DOD), other government agencies, and U.S. industry for major aeronautical programs. The program is based on a strong commitment to maintain American competitiveness in the world aviation marketplace, enhance the safety and capacity of the national airspace system, and help assure U.S. aeronautical superiority for national security.

The FY 1991 estimate reflects the need to address critical barriers and strengthen technology development in selected high payoff areas that are vital to our long-term leadership in aviation. NASA's FY 1991 aeronautics program is focused on achieving the long-term objectives established in the report, "National Aeronautical R&D Goals: Technology for America's Future," by the Office of Science and Technology Policy (OSTP), and by its sequel report, "Agenda for Achievement," which enunciates an eight-point action plan for achieving the goals.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The Aeronautics program has been reduced by a total of $13.1 million--$7.3 million as part of the overall general reduction and $5.8 million due to sequestration. A separate line has been established for the high-speed research program (previously identified under high-performance aircraft systems technology) as a result of its importance and increased research emphasis.

BASIS OF FY 1991 ESTIMATE

The FY 1991 research and technology program is committed to addressing the critical issues associated with the U.S. air transportation system, to enhancing American competitiveness in the international marketplace, and to enhancing the margin of the country's preeminence in aviation for national security. Technologies are being pursued which have the potential to offer major advances in vehicle performance and capabilities and which could provide substantial positive impact on U.S. competitiveness. Research efforts have been expanded in several high payoff areas. The demands for NASA's unique wind tunnels are continuing to increase with the emergence of new civil and military aircraft programs. In order to ensure wind tunnel availability to meet these demands, a major five-year revitalization program was initiated to modernize NASA's major wind tunnels for productive use well into the next century. This revitalization program is entering its third year in FY 1991 and is the result of the realization that maintenance and repair of facilities and related instrumentation had been underfunded for many years. This problem is compounded by increased demand for facility utilization and sharp increases in material and labor cost. This submission provides for increased funding in maintenance of facilities to continue to reverse this situation.

A brief summary of the key elements of the research and technology base and systems technology programs follows:

Fluid and thermal physics research emphasis will be placed on analytical, computational, and experimental studies of turbulence and transition physics with emphasis on the supersonic flow regime. Research will also be conducted in hypersonic aerodynamics in two key areas: understanding boundary layer transition/turbulence, including the effects of real gases; and airframe/propulsion integration, for airbreathing hypersonic vehicles, through enhancements in computation and advances in powered and unpowered wind tunnel test techniques. Applied aerodynamics will include efforts in subsonic/transonic drag reduction and additional activities in configuration aerodynamics which focus on new, nonconventional planforms having improved maneuverability and performance for both subsonic and supersonic flight. Rotorcraft research will focus on major wind tunnel tests for noise reduction. Propulsion and power research will continue to emphasize improved understanding of the governing physical phenomena at the disciplinary, component, and subsystem level leading to future high-payoff improvements in capability and efficiency. Materials and structures research will continue to focus on developing advanced materials and innovative structural concepts aimed toward reducing aircraft weight and cost. Research in information sciences will continue to be focused on concurrent processing for ultra high-reliability and high-performance architectures which will be much more immune to hardware and software failures. Increased emphasis will be placed on software engineering for large, complex systems. Controls and guidance research will continue working toward providing a technology base which supports aircraft designs capable of safer and more efficient operation and having greatly expanded flight envelopes. Human factors research will continue to focus on flight management, human engineering methods, and cockpit

automation aids. Flight systems research will be directed toward the aeronautical technology needs of aviation safety, flight test methodologies, and current and future high-performance aircraft. The high angle-of-attack research and technology base development, which was augmented in FY 1990, will continue to be expanded and accelerated in critical discipline areas. Emphasis will be placed on the accelerated development of critical integrated control technologies using thrust vectoring to attain and control flight at post-stall conditions. A research program in short takeoff and vertical landing technologies will be continued to provide these capabilities for future high-performance aircraft. Systems analysis studies will continue to focus on defining research and technology needs for civil and military aircraft and on developing advanced analytical techniques and modeling capabilities to conduct credible sensitivity studies and tradeoff analyses.

In materials and structures systems technology, the advanced high-temperature engine materials program will focus on the development of metal-matrix and ceramic-matrix composites. The advanced composite materials technology program activities will include development of organic polymers for high-temperature thermoset and toughened, easily processible thermoplastic composites for use in the 300 to 600 degrees Fahrenheit range. These materials will be incorporated in advanced structural concepts to identify opportunities for reducing composites fabrication cost using filament winding, pultrusion, and/or thermal forming processes. In rotorcraft systems technology, noise and vibration prediction methods will be validated for tiltrotors, and innovative noise control concepts will be explored. Download abatement for tiltrotors will be flight tested. High-speed concepts will be explored in small-scale tests for proof-of-concept validation. In high-performance aircraft systems technology, research will continue to concentrate on the application of flight/propulsion controls integration for enhanced mission effectiveness. In advanced propulsion systems technology, several advanced technology concepts for future aircraft propulsion will continue to be explored and exploited, including advancements in commercial aviation turboprop and general aviation small gas-turbine engines (e.g., efficiency increases, noise reduction). In numerical aerodynamic simulation, the third high-speed processor will be in its first full year of operation. Other elements of the extended operational configuration will be enhanced in the areas of advanced graphics, sophisticated work stations, Unix-based mass storage system, and upgraded communications for local and remote users. The high-speed research program will build on efforts initiated in FY 1990 to resolve critical environmental issues including effects on ozone depletion, airport noise, and sonic boom in a manner that will allow the U.S. to make future informed decisions on high-speed civil transport technology development.

BASIS OF FY 1991 FUNDING REQUIREMENTS

RESEARCH AND TECHNOLOGY BASE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
	(Thousands of Dollars)				
Fluid and thermal physics research and technology	32,062	33,500	32,100	32,200	RD 12-6
Applied aerodynamics research and technology	66,584	73,800	73,368	88,200	RD 12-8
Propulsion and power research and technology	69,078	71,500	69,002	75,700	RD 12-11
Materials and structures research and technology	39,158	40,500	39,969	41,400	RD 12-14
Information sciences research and technology	9,260	11,700	10,488	9,900	RD 12-17
Controls and guidance research and technology	35,598	37,000	35,082	37,300	RD 12-19
Human factors research and technology	17,702	17,800	17,310	17,800	RD 12-21
Flight systems research and technology	30,801	39,800	38,955	40,600	RD 12-22
Systems analysis	9,320	10,100	9,848	10,300	RD 12-24
Total	309,563	335,700	326,122	353,400	

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Fluid and thermal physics research and technology............................	32,062	33,500	32,100	32,200

OBJECTIVES AND STATUS

Fluid and thermal physics research is performed to advance the understanding of fundamental fluid mechanics phenomena and to derive efficient aerodynamic prediction tools. The research includes efforts in fluid physics, computational fluid dynamics (CFD), CFD code validation, and viscous flow studies. The latter area includes laminar stability analysis, boundary layer transition, and analytical turbulence. CFD research is performed for the prediction and simulation of complex fluid flows over aircraft. The validation of prediction and simulation methods is accomplished by means of a coordinated experimental test program. This activity also provides improved insight into the fundamentals of flow physics, as well as the detailed flow measurements required for verification of the computations. Viscous flow research is conducted with emphasis on developing specific devices and design techniques to reduce overall aircraft drag.

Numerous advanced solution algorithms have been generated for complex viscous flows, and innovative grid techniques developed to resolve the added geometrical complexity of realistic three-dimensional configurations. These new algorithms and gridding techniques were tested for three-dimensional geometries at transonic and supersonic speeds. To assess the accuracy and reliability of these new techniques and codes, both computational studies and experimental verification activities are in progress. Significant advances have been made in the enduring problem of understanding, predicting, and modeling the onset and structure of turbulence. The Center for Turbulence Research at Ames Research Center completed a highly successful first year of operation with coordinated efforts in theoretical computational and experimental turbulence physics. Experiments were identified to be conducted to generate the data for turbulence modeling and code validation. Drag reduction flow research efforts have focused on laminar flow control, natural laminar flow concepts, and turbulent skin friction drag reduction. The development of surface geometry modifiers included research to extend proven concepts such as riblets and large eddy breakup devices to supersonic speeds. These passive friction reduction techniques have also been applied to the control of flow separation associated with shock wave/boundary layer interaction.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a total decrease of $1.4 million. Of this $0.3 million is associated with the general reduction, which was accommodated by reducing the areas of computational methods and applications, computational fluid dynamics validation, and drag reduction. An additional $1.1 million of facility requirements was realigned from this program to the applied aerodynamics program within the research and technology base.

BASIS OF FY 1991 ESTIMATE

In FY 1991, CFD research will be directed toward development of faster and more efficient numerical algorithms to facilitate full Navier-Stokes solutions including flows with large wall curvatures and jet ejection. Improved methods will be derived for numerical simulation of aerothermodynamic flow phenomena associated with hypersonic cruise and maneuver vehicles including real-gas chemistry. Enhanced computational capabilities will be sought through development and use of advanced computer architectures and expert system concepts. Sophisticated, generic Reynolds stress turbulence models exhibiting greater flow realism and wider applicability will be generated. Research will be initiated to acquire a detailed data base for propulsive-lift flow interactions with the ground. Transonic data bases necessary for validation of CFD codes simulating transports and other configurations will be produced. Increased emphasis will be provided for validating supersonic and hypersonic flow analyses.

Drag reduction research will continue to emphasize the development of the hybrid laminar flow concept for reducing viscous drag at transonic and supersonic speeds. Also high-speed turbulent skin friction reduction techniques will be pursued. Passive and active concepts will be explored for flow control separation for drag reduction, stability improvement, and vehicle control. Fundamental flow mechanism investigations will include the study of turbulent flow coherent structures and boundary layer transition physics. Turbulent skin friction reduction devices, such as surface geometry modifiers, will be explored for the supersonic regime. Vorticity control concepts will be investigated for preventing flow separation. Hypersonic stability and boundary layer transition analyses will be performed to derive transition prediction techniques. CFD methods will be developed for slender bodies and highly swept wings characteristic of supersonic cruise configurations, including emphasis on interacting vortex flows, wing leading-edge radium effects, and variable camber devices. Emphasis will be placed on validation of transition methods for highly swept wings at supersonic speeds.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Applied aerodynamics research and technology	66,584	73,800	73,368	88,200

OBJECTIVES AND STATUS

This program's objective is to provide new, validated technology applicable to future U.S. military and civil aircraft from subsonic to hypersonic speeds. The approach is to conduct comprehensive ground and flight experiments involving realistic vehicle configurations and key configuration components. Such work is focused on areas expected to render major gains in advanced vehicle performance. Products include new analytical and experimental methods needed in the design process and new aerodynamic concepts. This work covers the full spectrum of civil and military air vehicles, including both rotary-wing and fixed-wing concepts, and also includes the area of aeroacoustics.

Configuration aerodynamics research identifies and analyzes innovative aerodynamic concepts. This program uses wind tunnel, water tunnel, and flight experiments to complement analytical aerodynamic developments for complex flows over aircraft components and configurations. Advanced computational algorithms are developed for exploring vortex interactions. Cellular formation studies are underway for the derivation of separated flow control techniques.

In subsonic aerodynamics, the research emphasis is on induced drag reduction and separated flow control to reduce aircraft drag and improve aircraft stability and control. Novel approaches to achieving lower induced drag are being investigated in the form of unconventional wing planform (e.g., crescent) and sheared wingtip shapes. Flight tests are also conducted to support industry applications of spin-resistance technology to new aircraft designs.

Significant advancements continue to be made with application of fixed-wing sophisticated codes to rotorcraft. Experimental validation of these methodologies is required both for helicopters and for higher speed rotorcraft. Comprehensive testing requires detailed, simultaneous measurement of pilot motions, vehicle response, vibration, noise, loads, and blade pressures. This data will support the light experimental helicopter program of the Army. Key areas for payoff are in tiltrotor download, noise, maneuverability and control integration. Promising new areas of emphasis in rotorcraft include higher harmonic control, aeroelastic tailoring, optimization and boundary layer control. All of these ideas have indicated payoff but must be shown to be practical for low risk application.

The high-performance (fighter/attack) vehicle research program is focused in three key technology areas: short takeoff and vertical landing (STOVL), high angle-of-attack maneuverability, and supersonic cruise and maneuver. In the STOVL arena, research is directed toward development of computational fluid dynamic and empirical methods to predict the complex flow surrounding a hovering jet-borne vehicle, especially near the ground; and flight dynamic simulations of transition between hover and forward flight. In the area of high angle-of-attack, both new experimental and analytical methods are being developed for the prediction and control of the separated and vortex flows which will allow advanced, high-performance aircraft to push beyond the traditional stall barrier by virtue of increased stability and control. In the supersonic cruise arena, new nonlinear prediction and design methods for advanced airfoils and wing planforms are being developed to improve cruise efficiency and maneuverability of advanced fighters.

Research is performed to derive advanced techniques and instrumentation for more accurate and efficient testing, both in wind tunnels and in flight, to validate the analytical methods. Instrumentation research has emphasized high-speed flow sensing to support U.S. initiatives in supersonic and hypersonic vehicles. Concepts to be investigated include global methods which sense parameters over large areas of the flow field simultaneously, fluorescent paint applied to wind tunnel models which senses changes in stream pressure, and real-time interferometry techniques for unsteady flow.

The development of advanced turboprops has led to increased concerns for enroute noise. Advanced turboprops generate low-frequency, periodic noise signatures which, even when operating at cruise altitudes, can be audible at ground level. However, due primarily to atmospheric propagation effects, the noise levels received at the ground are highly variable. The fundamental aeroacoustics program focuses on obtaining a better understanding of, and improved prediction capability for, topographical and atmospheric propagation effects.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a decrease of $0.4 million. This reflects a $0.9 million share of the general reduction, which was applied across a number of elements within this program, including configuration aerodynamics, fighter/attack aircraft, generic hypersonic research, and national transonic facility (NTF) operations, as well as a reduction of $1.7 million due to sequestration, accommodated in the areas of generic hypersonic research and NTF operations. These decreases were offset by an increase of $2.2 million of facility requirements realigned from other research and technology base programs.

BASIS OF FY 1991 ESTIMATE

Technology will be developed for the timely and efficient design of new advanced airfoil and aircraft configurations and for the development and evaluation of improved aerodynamic and analysis methods. NASA/industry cooperative efforts involving CFD and wind tunnel and flight research to address stability and control issues with sheared wing tips will be initiated. Flight tests to evaluate the handling qualities of natural laminar flow wings will be completed. Development of transition mode and sensor instrumentation will continue in a flight research program. Increased support for high-lift research will be directed at developing computational methods and evaluating advanced concepts for next generation subsonic transports. Problems associated with maintenance and repair of facilities and related instrumentation, which have been underfunded for many years, are being partially remedied in FY 1991.

Research efforts will be made to acquire a means of predicting three-dimensional wing flow separation. An advanced vortical flow analysis method to predict wing and wake flows at high angle-of-attack attitudes will be sought. Research will be performed to acquire an improved understanding of wing/body vortical flows to include insights into vortex prediction and breakdown phenomena. Three-dimensional viscous flow interaction phenomena will be explored through analytical and experimental approaches.

A joint program is underway between NASA, the U.S. Army, and industry to conduct an experimental flight investigation with a highly instrumented UH-60 Black Hawk helicopter. A full-scale rotor will be tested in the 40x80-foot wind tunnel to examine individual blade control and a low noise airfoil. Simulation for flight dynamics research will address rotor state control for increased maneuverability. A joint program with the Army will test a scaled tiltrotor for detailed noise and loads. The optimization analysis for rotor blades will require a multidisciplinary approach, including aerodynamics, dynamics and structural design for performance enhancement.

High-performance research in STOVL will continue the development of predictive methods of propulsion-induced aerodynamics for STOVL aircraft and ground environment issues, such as force and moment generation, ground erosion, acoustics and hot gas ingestion. Hover tests, both in and out of ground effect, of a large-scale advanced powered-lift fighter concept will be completed. Computational fluid dynamic codes will be developed for analysis of complex STOVL configurations hovering "in ground effect." High angle-of-attack research will continue development of analytical predictions of post-stall aerodynamics and comparisons with wind tunnel and flight test data. Supersonic research will extend the analytical modeling methods to include solution-adaptive grid refinements; applications to arbitrary, complex geometries; and the development of techniques to predict aerodynamic control surface effectiveness and the characteristics of thrust vectoring nozzles.

Advanced methods will be pursued for accurately sensing and handling aerodynamic flight test data, both boundary layer and off-surface flows. Measurement techniques for time-varying turbulent velocity fields will be explored. Development of three-dimensional wind tunnel adaptive wall techniques will be continued.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Propulsion and power research and technology	69,078	71,500	69,002	75,700

OBJECTIVES AND STATUS

The objective of this program is to provide the increased understanding of the governing physical phenomena occurring at the disciplinary, component, and subsystem levels that will support and stimulate future improvements in propulsion system performance capability, efficiency, reliability, and durability. Research is conducted in a wide variety of subsystems with applications ranging from general aviation through the hypersonic aerospace plane. Ongoing disciplinary research on instrumentation, controls, internal fluid mechanics, and aerothermodynamic concepts is providing the foundation necessary for continued advancement at the component and subsystem level. These research efforts will lead to high-payoff propulsion system improvements which have historically provided a major share of aircraft performance advances and also enabled new classes of vehicles.

In the discipline areas, internal computational fluid mechanics continues to be an increasingly important tool for understanding flow phenomena and improving designs of aeropropulsion systems. Advanced algorithms and analysis methods are being developed for complex three-dimensional flows in inlets and nozzles, turbomachinery and chemically reacting flows. In 1990, a two-dimensional steady viscous reacting flow code that incorporates real-gas properties and is capable of high-speed hydrogen-air combustion solutions will be improved with an advanced probability density function (PDF) turbulence model. Additional data on turbulent reacting shear-layer flow data sets will be obtained for verification using nonintrusive diagnostic techniques such as planar laser-induced fluorescence and laser Doppler velocimetry. In addition, experiments will be conducted to determine turbine blade unsteady heat transfer characteristics in an annular rotor cascade facility. Instrumentation and control research is aimed at developing advanced high-temperature sensors, optical nonintrusive measurement systems, and advanced engine sensors and controls for future propulsion systems. In 1990, laboratory evaluations will demonstrate a long wavelength pyrometry technique for application on ceramic/composite propulsion system components. The capability for making near-wall two-component velocity measurements with a four-spot laser anemometer will be demonstrated in a small centrifugal compressor facility in support of boundary layer code development and verification.

For subsonic transport propulsion research, the objective is to develop the fundamental technologies to improve the thermal efficiency of advanced subsonic power plants by 20 percent and propulsive efficiency by 15 to 20 percent. In 1990, concept studies will be completed that identify specific concepts and research needs for thermal efficiency improvement. Basic turbomachinery research will continue with the fabrication of a low-speed axial turbomachinery rig, development of an analytical code for flutter and forced response predictions, and a subsonic compressor cascade experiment to understand the effects of blade motion on unsteady aerodynamics. General aviation engine research is aimed at rotary engines with the objectives of reduced fuel consumption, an increased power density, and multifuel capability. Stratified-charge rotary engines have demonstrated the goals for multifuel capability and power density. The fuel consumption is being reduced through the application of advanced analytical codes to improve the design of the combustion chamber. In 1990, an 0.38 brake specific fuel consumption (BSFC; lbs/bhp-hr) with a maximum power density of 5 horsepower per cubic inch will be demonstrated experimentally.

In supersonic cruise research, the objective is to develop technology for efficient, environmentally compatible propulsion concepts for Mach 2 to 6 cruise operating conditions. In 1990, studies will be completed to determine the potential and technology needs for operating turbomachinery-based propulsion systems at Mach numbers approaching 6. Conceptual designs of turbomachinery modules will be completed for subsequent experimental evaluation at high inlet temperatures and pressures representative of a high Mach flight condition to determine aeroelastic response and provide analytical code validation data. For high-performance applications, the goal is to develop propulsion systems technology for powered lift and thrust vectoring that will lead to improved aircraft short takeoff and vertical landing (STOVL) and supermaneuvering capabilities. Principal activities during FY 1990 will include a complete experimental evaluation of full-scale ejector performance for a mixed-cycle configuration using heated primary air and the completion of a design study to determine optimum configurations for diverter valve concepts.

The hypersonic propulsion research objective is the development of the basic understanding of high-energy fluid phenomena, dynamic models, advanced concepts, and the diagnostic and facility technologies for high-speed cruise at Mach 6 and above. In 1990, mixing enhancement concepts will be evaluated both analytically and experimentally to improve the rate of mixing in supersonic combustion ramjet (scramjet) combustors. Nonintrusive diagnostics will be used to define the details of turbulent mixing and combustion in a practical scramjet combustor flowfield for use in validation of advanced analytical codes. Sidewall compression inlet experiments will be conducted up to Mach 18 in helium wind tunnels to provide detailed data for calibration of computational methods and comparison to two-dimensional inlets.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects an overall decrease of $2.5 million primarily in hypersonic research, $1.5 million as a part of the Congressional general reduction and $1.0 million resulting from sequestration.

BASIS OF FY 1991 ESTIMATE

Discipline research in internal computational fluid mechanics will continue on advanced prediction capabilities that are three-dimensional, viscous, and include reacting flow and heat transfer, with increased emphasis on turbomachinery prediction capability and flow physics. A three-dimensional, viscous rotor/stator code will become operational and will be evaluated for accuracy and ability to predict the important flow physics using time-resolved, experimental data obtained during a test of a high-speed compressor stage using nonintrusive diagnostics. Validation of three-dimensional supersonic flowfield prediction capabilities will begin by obtaining detailed experimental data for separated flow regions and for supersonic shear layers subject to excitation for enhanced mixing and reduced near-field acoustics levels. Advanced instrumentation and control research will continue to focus on the development of nonintrusive optical sensors, high-temperature electronics, and the growing need and advantages of propulsion/airframe integrated controls. Instrumentation research will include a facility demonstration of a multipoint, multiparameter nonintrusive flow diagnostic system. Controls research will include completion of a flight test of a prototype fiber-optic position encoder as the first step in the demonstration of an integrated fiber-optic control system capability. Increased emphasis will be made on preventive maintenance and repair of research facilities.

Subsonic transport research will include the completion of the axial low-speed multistage flow physics facility for turbomachinery in preparation for the acquisition of a viscous blade row interaction experimental data base for turbomachinery code verification and closure model development. General aviation engine research activities will continue to focus on advancing rotary engine technology. Advanced components using lightweight, heat-resistant materials, together with advanced computer modeling for improved designs, is expected to lead to attainment of the fuel efficiency goal of 0.35 BSFC and improvements in power density to 6 horsepower per cubic inch.

Supersonic cruise research will continue the development of advanced propulsion concepts such as innovative turboramjet-type cycles offering improved high-speed efficiency and flight envelope expansion. Research will be accelerated for high-speed inlets with the demonstration of an analytical capability to predict inlet unstart mechanisms. It is planned that this research will lead to the capability to adjust shock waves and boundary layers in inlets, resulting in full three-dimensional control of inlet flowfields. In the area of high-performance aircraft research, efforts will continue to concentrate on supermaneuverability and STOVL technologies for future fighter aircraft. Inlet model testing at high angle-of-attack will be completed and results used to validate a three-dimensional Reynolds-averaged, unsteady, compressible Navier-Stokes code. The exhaust gas ingestion effects data base will be completed and the results used to validate an advanced three-dimensional multigrid code (currently under development) that will be used to investigate the effects of STOVL aircraft and ground environments on propulsion system designs and engine operating dynamics.

Hypersonic propulsion activities will include evaluations to provide an understanding of high-speed inlet flow physics, exhaust system flow physics and associated flow chemistry, mixing mechanisms necessary for complete heat release, high-speed combustion, and the interaction of scramjet engine components. Experimental investigations will include inlet flow mapping from Mach 5 to 14, nozzle flow mapping to determine flow migrations and the effect of sidewall and splitter geometry, subcomponent evaluation of hypervelocity mixing and combustion enhancement techniques, and evaluation of a small-scale scramjet to obtain engine unstart data induced either by the inlet or combustor. These experiments will be guided by, and the results compared to, advanced three-dimensional flow analysis codes that have the capability to resolve separations in the flow, flow chemistry, and heat transfer rates. Specific analytical research will include development of an advanced turbulence/mixing model, calculation of radiative cross-sections for all important transitions in air species, and prediction of nozzle/afterbody flowfield with high-speed reacting flow codes.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Materials and structures research and technology	39,158	40,500	39,969	41,400

OBJECTIVES AND STATUS

The objectives of this program are to: (1) develop and characterize advanced metallic, intermetallic, ceramic, polymer, and composite materials; (2) develop novel structural concepts and design methods to exploit the use of advanced materials in aircraft; (3) advance analytical and experimental methods for determining the behavior of aircraft structures in flight and ground environments; and (4) generate a research data base to promote improvements in performance, safety, and durability of aircraft, as well as reduce the weight and life cycle cost.

Research in materials is directed toward airframes and high-performance gas turbine engines. In airframe materials research, studies are being conducted in advanced materials for high-temperature applications including new thermoplastic polyimides and advanced metallic materials, processing methods for superplastic forming of aluminum alloys, light alloys such as aluminum-lithium, and intermetallics. Engine materials research focuses on advanced metals, intermetallics, ceramics, fiber-toughened ceramics, and polymers.

Aircraft structures research is focused on developing innovative concepts for airframes and engines that are lightweight, durable, and cost-effective. Primary areas of research are advanced analytical methods to predict structural response, multidisciplinary analysis and optimization to predict aerodynamic and acoustic loads and improve design methodology, understanding fatigue and fracture mechanisms to improve reliability, and low-cost fabrication methods.

Research in aeroelasticity includes computational methods to predict flutter and performance of aircraft; control concepts to improve performance, enhance stability and reduce loads; and development and testing of advanced aircraft configurations. Activities are balanced between the needs of civilian aircraft to improve competitiveness and national defense needs for high-performance aircraft. Hypersonic research is directed toward developing lightweight material systems and structural concepts that can withstand the very high temperatures encountered during hypersonic flight.

Methodologies will be developed and verified for fatigue and fracture analysis, quantitative nondestructive evaluation (NDE), and structural life prediction technologies required to ensure the long-term safety of aging airframe structures which experience fatigue cracking and/or corrosion damage.

Specific goals of this research include the development of comprehensive crack initiation/growth methodology applicable to multisite cracking in complex riveted joints, global/local structural analysis methodology for predicting crack growth in stiffened shell structures, and innovative NDE technologies to accurately and economically detect fatigue/corrosion damage in aging aircraft.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a decrease of $0.5 million as a portion of the general reduction in the areas of airframe and propulsion materials and structures.

BASIS OF FY 1991 ESTIMATE

In FY 1991, the materials program will continue to place a strong emphasis on developing basic understanding and technological relationships among processing parameters, microstructure and properties of metallic, intermetallic, ceramic, and polymeric materials, including both monolithic materials and composites, with particular focus on high-temperature applications. New organic composite materials for long-term applications at elevated temperature will be developed along with innovative powder processing and fabrication methods. New opportunities in both monolithic and reinforced advanced light alloys for airframes and cryotankage will be pursued. Innovative advances in intelligent processing of materials utilizing advanced sensors and artificial intelligence will be sought for selected high-temperature materials, such as intermetallic composites, which are especially difficult to process and fabricate. Efforts will continue toward developing characterization parameters and failure criteria for time-dependent deformation, fatigue and fracture of complex reinforced materials under service conditions which include both mechanical and thermal loading. Constitutive models and computational methods for monolithic and composite materials will be developed to predict responses to combined thermal, mechanical and environmental conditions.

Airframe structures research will continue to emphasize the mechanics and fundamental behavior of composite structures and innovative concepts for use of light metallic structures. Specifically, during FY 1991 development of a post-buckled panel design optimization code for application to composite panels under combined loading will be completed. Post-buckled behavior of composite panels and shells will be investigated to examine the influence of penetrations and cut-outs. Propulsion structures research will focus on development of an engine structures computational simulator to integrate thermal, structural and aeroelastic analysis to evaluate concepts for composite engine structures and advanced actively controlled bearings.

Advanced analytical methods will continue to be developed in the computational structural mechanics (CSM) program including probabilistic analysis and boundary elements for the structural analysis of airframes and engines. In addition, an expanded program will be developed in computational structures technology (CST) that will integrate materials, micromechanics, and large-scale structural analysis into a cohesive computational discipline and establish interfaces with additional discipline areas.

Aging aircraft research will focus on developing analysis methods for critical crack configurations, including multisite damage, and predicting failure in complex built-up structures. The NDE effort will focus on developing NDE methods to reliably detect lap joint debonding, multisite cracking and corrosion in fuselage panels and actual fuselage structures. NDE research will also focus on developing advanced noncontacting wide-area methods of NDE, such as thermal imaging and optical displacement techniques, which are applicable to detecting fatigue and corrosion damage in aging aircraft fuselages.

The aeroelasticity research activity will develop computational models to predict unsteady aircraft loading and aeroelastic response using advanced Euler methods and will develop control laws to reduce maneuver loads for a flexible, actively-controlled wing. A Navier-Stokes method will be developed to compute the unsteady aerodynamic loading and aeroelastic response of wing-body configurations. The effects of damping and blade mistuning will be incorporated into the analysis of counter-rotating turboprops, and research will continue to understand the aeroelastic response of supersonic flow through turbomachinery.

Interdisciplinary research will develop efficient optimization methods for coupled structural design of wings and main rotors. The ability to integrate multidisciplinary design conditions and constraints will be demonstrated on a complete aircraft configuration.

In hypersonic research, integrated flow/thermal/structural analysis methods will be developed and verified for accurate mission loads prediction to aid the development of lightweight, efficient, and durable airframe and propulsion systems. High-temperature materials research will focus on ceramic composites, intermetallic composites, and carbon/carbon, constitutive behavior, and oxidation-resistant and thermal barrier coatings. New materials and structural concepts will be evaluated for actively cooled hot structures.

		1990		1991
	1989 Actual	Budget Estimate	Current Estimate	Budget Estimate
		(Thousands of Dollars)		
Information sciences and research technology..........................	9,260	11,700	10,488	9,900

OBJECTIVES AND STATUS

This program provides the fundamental capabilities to: (1) exploit advanced computer architectures to meet NASA's unique computing requirements; (2) increase the agency's ability to develop high-quality aerospace systems software; (3) provide the advanced theory, concepts and capability to effectively use and manage aerospace information; and (4) provide advanced measurement technology for ground-based aerodynamics, aerothermal and propulsion test facilities, and flight research programs. Effective exploitation of computational modeling of physical processes, such as computational fluid dynamics (CFD), will be enhanced through the development of a fundamental understanding of the relationship between physical algorithms and advanced parallel processing architectures. Research on the theoretical foundations for managing complex software systems and on the development and validation of reliable software is directed toward improving the quality and cost of complex mission-critical software.

Parallel processors offer the potential for enabling numerical simulation at affordable costs. A fast Fourier transfer algorithm and new preconditioners and sparse matrix solvers were developed and implemented on parallel processors, including the Connection Machine (CM-2). An Intel parallel processor system was acquired at Langley Research Center for computer science research. Evaluating performance of parallel processors is an important problem to both computer systems architects and application developers. Common interfaces were established for all sparse distributed memory (SDM) simulators including the Stanford prototype and the CM-2 simulator, and the CM-2 SDM simulator was released for evaluation. Evaluation of neural network architectures in a fault-tolerant environment was begun. Capability to handle pipelined instructions was added to the computer architect's workbench.

The University of Illinois conducted research tasks addressing the reliability and development of complex mission-critical software. A fault-tolerant consensus voting technique was evaluated, and the effectiveness of code-based testing techniques was quantified. The automated programming subsystem of the computer-aided software engineering tools was completed.

The high-speed mainframe computer networking subsystem is providing NASA aeronautical researchers remote access to the agency's mainframe computers. Examination of the need for network expansion was conducted. In the generic hypersonics area, the fiber optics/detector signal-to-noise ratio analysis for a fiber-optic microphone was completed.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $1.2 million, which includes $0.2 million of the general reduction, accommodated in the information management area, and $1.0 million for sequestration in flight instrumentation and precursor work in support of the high-performance computing program.

BASIS OF FY 1991 ESTIMATE

Research on the use of novel parallel processors controlled by new algorithms for efficient numerical simulation will continue at the Research Institute for Advanced Computer Science (RIACS). Performance of special purpose CFD computers, including a systolic processor and the Navier-Stokes machine, will also be evaluated. The research will address other aerospace applications of parallel processing including computational structural dynamics and visual research. Research in sparse distributed memory, developed as a mathematical model of human long-term memory with the properties of associative recall, will continue. The ultimate capability of such a memory could include computer vision and natural language. The applicability of the sparse distributed memory to a selected flight control problem will be examined. A research program in networked systems to examine the interactions and underlying capabilities provided by systems of computers, experimental facilities, and humans connected by networks will be conducted. The focus is on the architecture of such distributed systems and the resulting requirements for network function and performance.

Software engineering studies will continue to quantify the reliability gained from formal specification, software prototyping, computer-aided software engineering systems, software reuse, and formal verification. The Institute for Computer Applications in Science and Engineering will conduct research in these areas, and in parallel computing. The block grant at the Illinois Computing Laboratory for Aerospace Systems and Software will address characterization and evaluation of automated support tools for increased reliability in software specification and design, including Ada programs.

NASA will support the enhancement of computer networking to provide for the effective and productive use of NASA's distributed computing resources. Fiber optic microphone operation to 2000 degrees Fahrenheit will be demonstrated for hypersonic-flight research.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Controls and guidance research and technology	35,598	37,000	35,082	37,300

OBJECTIVES AND STATUS

This program provides a technology base supporting future aircraft designs for safer and more efficient operations and greatly expanded flight envelopes. Specific program objectives are to: (1) exploit emerging controls, guidance, and artificial intelligence technologies for the development of advanced automation concepts for applications including rotorcraft nap-of-the-Earth (NOE) flight, and more efficient operations within the National Airspace System; (2) develop highly reliable system architectures and validation methods for flight crucial systems; (3) develop airborne windshear detection sensors and avoidance techniques; (4) develop advanced control and guidance theories, concepts, and analysis methods; and (5) develop new methodologies for achieving multidisciplinary integration.

Knowledge-based control and guidance concepts have been shown to be feasible for improving system design, performance, and crew-vehicle interface. Research culminating in flight test has demonstrated reduced development time and added in-flight capability for an aircraft system redesigned using knowledge-based system techniques. Analytical methods, assessment techniques, experimental methodologies, and the AIRLAB facility have been developed for the evaluation and validation of fault-tolerant, concurrent processing, and distributed computer systems for aircraft applications. Multiple tools and software codes are now distributed to and in use by industry.

Three alternate technologies for in-flight detection of windshear are currently under development for flight test evaluation. The windshear hazard index and microburst models for dynamics and structures applications have received wide industry acceptance. As high order dynamics becomes more important to aircraft performance, safety, and efficiency, the integration of numerous heretofore specialized disciplines has become a critical necessity. Multidisciplinary techniques for integrating controls, guidance, propulsion, structures, and cockpit systems are being pursued. Structures and controls disciplines have been integrated, in coordination with the efforts in the materials and structures R&T Base, to design flutter suppression control laws for an active flexible wing that are being evaluated in wind tunnel testing.

Advanced air traffic flow control concepts and the integration of four-dimensional-equipped aircraft into the National Airspace System are currently under study to improve the efficiency of air traffic control (ATC) operations. Both simulation and flight tests will be continued and plans for transitioning this technology to the Federal Aviation Administration will have been developed in FY 1990.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $1.9 million, which consists of a realignment of facility requirements ($0.5 million) to the applied aerodynamics program, $0.4 million reduction in the flight crucial systems and rotorcraft, as a part of the general reduction due to sequestration, and $1.0 million in simulation facilities.

BASIS OF FY 1991 ESTIMATE

Methodologies for efficient design of flight critical systems will be developed, accounting for the effects of electromagnetic interference on fault-tolerant processors and fault-tolerant architectures. Piloted simulation evaluations of an airborne windshear detection and avoidance system will be conducted. Use of datalink for transferring information between ATC and aircraft will be investigated in Transport Systems Research Vehicle (TSRV) flight tests.

Multidisciplinary methods will be developed to design control systems for vehicles with highly integrated dynamics, such as hypersonic and supersonic transports. Handling qualities criteria will be defined for hypersonic vehicles. Terminal area flight tests of a differential global positioning system will be conducted to determine the achievable accuracy using the precision code signal. A system identification methodology will be developed for aircraft with stability augmentation.

Control laws which provide maximum maneuverability and controllability during high angle-of-attack air combat maneuvers will be defined using piloted simulation and ultimately demonstrated on the High Alpha Research Vehicle (HARV). A real-time, expert-system-based flight test status monitor will be evaluated in simulation. A three-dimensional obstacle avoidance algorithm for use in automated NOE flight will be demonstrated on a graphics workstation.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology....	17,702	17,800	17,310	17,800

OBJECTIVES AND STATUS

The objective of this program is to provide the capability to design effective crew-cockpit interfaces and air traffic control (ATC) interfaces with the aircraft. Advanced automation technologies, along with increased traffic density, challenge the diverse systems, human operators, and their procedures. The goal of the program is to provide a human-centered technology which is safe, productive, efficient and effective for advanced commercial and military aircraft, rotorcraft, and other national aeronautical applications. There are five areas of emphasis: (1) flight management, (2) human engineering methods, (3) aviation safety/automation, (4) rotorcraft, and (5) subsonic transports.

In the flight system management area, FY 1990 research is expected to result in identification of the pilot's visual cues and performance when landing at a nose high altitude in poor visibility conditions. After a series of full-mission simulations, the effects of new automation technology on crew performance will be completed. A new panoramic display concept will be compared with conventional head-down displays.

In the human engineering area, a simulation-based validation to predict pilot boredom will be completed.

In the aviation safety/automation program, started in FY 1989, an assessment on pilot acceptance of a situational awareness response advisor concept which allows pilots to receive recommended actions subsequent to onboard fault detection is expected to be completed. Simulation studies will be accomplished on pilots' performance with TCAS (traffic alert and collision avoidance system) II and III in "all glass" cockpits. Both simulation and live traffic studies of advanced air traffic control automation tools will be continued to verify their adequacy and effectiveness.

In the rotorcraft research area, several studies on advanced aural and visual helmet-mounted displays, and new geographical orientation map displays will be completed. Causes of accidents and incidents during medical evacuation helicopter flights were identified and data gathered which will be used to improve a preflight risk-assessment device.

In the subsonic transport research program, several studies have been completed on pilot performance under conditions of two-person crews in advanced long-haul, multiple time zone flights to determine effective countermeasures to circadian desynchronosis. A preliminary prototype of an expert system will be developed which incorporates these results for scheduling flight crews.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects an overall decrease of $0.5 million. This includes a realignment of $0.3 million of facility requirements to the applied aerodynamics program and $0.2 million of the general reduction, which has been accommodated in the aviation safety/automation element of the program.

BASIS OF FY 1991 ESTIMATE

Research will continue on methods whereby flight crew performance will be improved and human error opportunities reduced. The flight management area will be directed toward test and evaluation of three-dimensional displays for visual tracking of very precise flight paths and display of positions of multiple aircraft in vertical and horizontal range. Research will continue to provide verification of pilot performance enhancement through use of in-flight, computer-based fault detection and classification techniques. Methods of relating human performance predictions with measures of pilot workload will be conducted. Considerable testing and demonstrations will be performed on human-centered automation methods and techniques. New techniques of information exchange, management, and display in cockpits and at air traffic control (ATC) workstations which reflect various levels of automation will be tested. Guidelines will continue to be developed which will lead to intelligent, error-tolerant or error-resistant cockpits and ATC workstations which must function safely and effectively in the future automated ATC environment. Laboratory evaluations of new rotorcraft crew procedures and concepts for piloting and navigating under low levels of visibility and high workload conditions will be conducted.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Flight systems research and technology...	30,801	39,800	38,955	40,600

OBJECTIVES AND STATUS

The objective of this program is to improve and validate an advanced technology base for application by industry to future generations of aircraft. The program is organized into the following categories: (1) aviation safety, (2) flight instrumentation and test techniques, (3) fighter/attack aircraft, and (4) flight support. The activities within this program encompass advanced engineering techniques and the

establishment of the feasibility of concepts to ensure rapid applications of promising new technology essential to meeting one or more of the following goals: (a) reducing aircraft accidents resulting from weather effects (heavy rain and icing); (b) improving flight efficiency, enhancing data accuracy, and enabling the acquisition of needed information; and (c) establishing a technology base for the design of future fighter aircraft with unprecedented maneuverability at high angle-of-attack (up to 90 degrees) flight conditions and short takeoff and vertical landing capability. Support services are provided to flight research projects using standard aircraft for chase, airspeed calibration, remotely piloted research vehicle drops, and flight crew readiness training.

The heavy rain tests using the aircraft landing dynamics facility have been completed for high rain rates, and the lift loss caused by heavy rain has been established for a typical airfoil section. Testing continues to determine the effects of lower rain rates. A subscale model of a modern helicopter rotor is being tested in the icing research tunnel to obtain information to characterize shed ice trajectories and the sequence of ice shedding from helicopter blades. The short takeoff and vertical landing (STOVL) technology development program is continuing to focus on STOVL concepts which feature remote lift systems for jet-borne flight and mixed-flow propulsion concepts for wing-borne flight. The principal focus in STOVL under the flight systems research and technology program is on the development of integrated flight and propulsion control systems. Aerodynamic and propulsion prediction codes are applied to specific STOVL concepts to develop detailed math models which are used to define integration methods and design criteria. The airborne information management system has been used to develop near real-time vertical wind shear measurement techniques to support the National Space Transportation System. The high angle-of-attack program has been accelerated by the FY 1990 augmentation. Continued validation of prediction methods with wind tunnel and flight data are enabling aircraft designers to develop highly maneuverable advanced concepts and to design modifications for existing aircraft to enhance the performance. Advanced computational fluid dynamics (CFD) methods, developed under the applied aerodynamics research and technology program, have been employed to calculate the flowfield around the forebody, LEX, and wing with excellent comparisons to the F-18 aircraft. A national workshop was conducted in FY 1990 to report the progress in correlating CFD and flight-measured aerodynamic results. The critical design review for the multi-axis thrust vectoring system was completed and manufacturing was initiated. The thrust vectoring system will be installed on the F-18 research aircraft allowing the high-performance flight research program to be initiated.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $0.8 million, which includes a realignment of $0.2 million of facility requirements to the applied aerodynamics program and a $0.6 million reduction in the fighter/ attack aircraft research to accommodate the general reduction.

BASIS OF FY 1991 ESTIMATE

The emphasis in aviation safety will continue with the development of three-dimensional analytical codes for aerodynamic performance and ice accretion predictions. Small-scale tests will be conducted to acquire data on the accretion and buildup of ice on swept wings for code development and validation. Test data acquired from the aircraft landing dynamics facility will be analyzed to assess the aerodynamic penalties associated with heavy rain.

The high angle-of-attack research program will focus upon investigating the potential benefits and assessing the aerodynamic, propulsion system, structural, and flight control system interactions resulting from multi-axis thrust vectoring at high angles of attack. Prediction methods for high angle-of-attack aerodynamics will be validated through continued correlation of CFD, wind tunnel, and flight results. Emphasis will be placed on the accelerated applications of vortex control methods. These methods will be refined and designs developed for application to the F-18 HARV. In the STOVL program work on critical technologies will be continued, such as simulation models of flow diverter valves and ducts, integrated flight/propulsion control systems cruise and vertical landing nozzles, and ground environmental effects. These models will be used to validate the integrated controls design methods and to develop controls and handling qualities criteria for an advanced STOVL concept.

Development and flight evaluation of an advanced airborne information management system will continue. Flight tests and evaluation of a single-axis optical air data system will be conducted, and research will be initiated to develop a three-axis optical air data system suitable for use in flight.

Flight test support of flight research projects will continue using a variety of both fixed- and rotary-wing aircraft. These high-performance support vehicles will be flown as chase aircraft in support of research aircraft described under high-performance systems technology (X-29, F-18, F-15, F-16XL). Also included is specialized training for critical personnel, as well as maintenance of flight data facilities, aircraft instrumentation, and flight data processing.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Systems analysis........................	9,320	10,100	9,848	10,300

OBJECTIVES AND STATUS

This program conducts assessments of long-term technology requirements, identifies technology applications, and conducts sensitivity analyses and technology tradeoff studies from which effective research and technology programs can be developed to meet civil and military aeronautics requirements.

Conceptual designs are performed utilizing advanced analytical techniques in order to quantify potential benefits of emerging technologies. The studies identify high payoff, emerging technologies and opportunities which can lead to significant advancements or improvements in civil or military aircraft performance, enhance safety, reduce operating cost or resolve critical aeronautics issues. The systems studies effort also serves to expand and enhance current analytical techniques and modeling capabilities.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The systems analysis program has been reduced by $0.3 million as a part of the general reduction.

BASIS OF FY 1991 ESTIMATE

Studies to be performed will cover a wide variety of innovative propulsion and airframe concepts which can achieve significant improvements in performance and in economic factors. These analytical investigations will explore alternate concepts and advanced technologies to identify the most promising areas for future research. Advanced analytical techniques and modeling capabilities will be developed to provide in-depth, credible analyses of vehicle/mission technology requirements. Development of a NASA-wide integrated engine/airframe analysis system will be pursued with emphasis on incorporating multivariate optimization, expert systems, and parallel processing features.

Systems studies for high-performance aircraft will continue development of the knowledge base to effectively utilize emerging technologies to enhance fighter capabilities and to develop advanced configurations that maximize payoffs of advanced technologies. While emphasis will continue to be on supersonic short takeoff and vertical landing concepts, studies will also investigate the technology requirements for high-speed/long-endurance fighter/interceptor aircraft concepts. The initial phase of propulsion and airframe concepts assessment for high-speed rotorcraft systems will be complete in FY 1991. Continuing efforts will emphasize airframe/drivetrain/engine integration technology requirements, mission impact assessment, and development of an information base for long-range planning in the discipline research and technology programs.

Systems analysis studies for subsonic aircraft will develop the necessary analytical capabilities for defining technology requirements for advanced transport aircraft. The efforts will investigate requirements in areas of new, nonderivative configurations, advanced propulsion concepts, and economic considerations. Ongoing studies in the supersonic cruise vehicle class will assess the viability of a supersonic throughflow fan engine. Generic hypersonic studies will provide analytical support for advanced vehicle concepts and assess unique test facility and instrumentation requirements.

In the vehicle systems area, efforts will continue to develop advanced analytical capabilities. The focus will be on multidisciplinary airframe integration, advanced structural concepts and integrated propulsion airframe systems.

BASIS OF FY 1991 FUNDING REQUIREMENTS

SYSTEMS TECHNOLOGY PROGRAMS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
	(Thousands of Dollars)				
Materials and structures sy tems technology	19,200	30,300	29,595	39,900	RD 12-27
Rotorcraft systems technology	4,800	4,900	3,904	5,100	RD 12-29
High-performance aircraft systems technology	11,000	34,900	9,691	10,500	RD 12-30
Advanced propulsion systems technology	13,952	14,500	14,152	15,000	RD 12-31
Numerical aerodynamic simulation	39,685	42,500	41,798	44,100	RD 12-33
High-speed research	--	--	24,494	44,000	RD 12-35
Total	88,637	127,100	123,634	158,600	

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Materials and structures systems technology	19,200	30,300	29,595	39,900

OBJECTIVES AND STATUS

The objective of this program is to develop advanced materials and structural concepts for future aircraft propulsion systems and primary airframe structures. The materials and structures system technology programs build on fundamental research in polymers, metals, and composites conducted as part of the materials and structures research and technology programs.

Revolutionary advances in materials would enable 21st century transport aircraft propulsion systems with greatly decreased specific fuel consumption, reduced direct operating costs, improved reliability, and extended life. This will require very high thrust-to-weight (20 to 1) gas turbine engines with durable, long-life, hot-section components which can endure sustained operation without cooling air. Key to these applications are materials capable of operating at much higher temperature and strength levels than now possible. Materials currently in use, such as titanium alloys and nickel-based superalloys, offer only minor potential gains in performance. The candidate advanced materials include ceramic matrix composites, metal matrix composites, intermetallic matrix composites, and polymer matrix composites. These materials are vital to attaining higher turbine inlet temperatures for sustained supersonic cruise, higher thrust-to-weight engines for advanced high-performance concepts, and engine hot-section components without cooling air for greater efficiency. In addition, analytical codes to conduct design, predict life, and establish failure mechanisms will be developed to enable effective utilization of these new classes of materials by engine manufacturers.

Advanced materials and innovative structural concepts are being developed to fully exploit the benefits of composite materials for cost-effective primary aircraft structures. The program objectives will be accomplished through materials development, design and fabrication of innovative structural concepts, structural analysis and improved life prediction methods, and demonstration of improved structural performance through subscale and large-scale component tests. Advanced composite structures at the element/subcomponent are verified level as an essential building block leading to full-scale primary structures. Composite replacements for conventional metallic structures have demonstrated that organic matrix composites can reduce airframe structural weight for primary structures on fighter aircraft and helicopters, as well as medium primary and secondary structures on transport aircraft. Thus, this program

will focus on developing advanced toughened thermoset and thermoplastic composite materials; new structural concepts using cost-effective fabrication techniques such as advanced thermoforming, multidirectional weaving, pultrusion, filament winding and advanced fiber placement techniques, analysis, design and test methodologies to validate structural concepts; and analysis of failure mechanisms and methods for extending subscale laboratory tests to prediction of full-scale composite structural performance.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $0.7 million, including $0.2 million in high-temperature engine materials and $0.5 million in advanced composite materials research, as part of the general reduction.

BASIS OF FY 1991 ESTIMATE

Advanced high-temperature engine materials research will emphasize fiber development, matrix development, control and characterization of interfaces, as well as development of analytical models to guide composite materials development and predict their behavior under realistic environments. Strong, stiff, lightweight, oxidation-resistant reinforcement fibers which are capable of maintaining chemical stability and mechanical properties at elevated temperatures are key to this entire program. Research will focus on the development of silicon carbide, alumina, titanium diboride, chromium diboride, and beryllide fibers for reinforcing both intermetallic and ceramic matrices. This program also emphasizes the development of novel processing methods to combine the new fibers and matrices to produce composites. Structural mechanics research will focus on characterizing the mechanical behavior and failure mechanisms of composite materials under the combined influence of stress (both static and cyclic) and elevated temperature. This includes time-dependent, visco-elastic effects such as creep and creep-fatigue interactions. The elevated temperature response of composite surfaces and fiber/matrix interfaces under severe oxidizing conditions will be investigated. Mechanical testing methods, as well as the required sensors for measuring temperature and strain, will be developed for temperatures to 3000 degrees Fahrenheit and above.

Advanced composite materials and structures research will focus on developing technology for application of composites to primary airframe structures. This research will be directed toward exploiting new organic composite materials for use up to 600 degrees Fahrenheit and toward advanced processing and fabrication concepts for low-cost composite structures. Greater emphasis will be placed on developing and testing advanced wing and fuselage structural concepts. Increased funding will permit various subcomponent structural concepts to be designed and fabricated as part of the ongoing program to verify cost-effective manufacturing techniques coupled with innovative design concepts.

Wing structure subcomponents will be fabricated for structural testing using resin transfer molding and pultrusion fabrication processes to demonstrate the development of cost-effective primary composite structures. Advanced analysis methods will continue to be developed, including probabilistic modeling of composites for improved life prediction and analysis of composite failure mechanisms for innovative concepts such as stitched/woven laminates. Results from composite panel tests will be correlated with probabilistic modeling results to verify the validity of nondeterministic analysis methods for prediction of structural performance and failure mechanisms. These are essential components of the technology required for the full use of composite materials in advanced aircraft and will be used to analyze concepts being developed.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Rotorcraft systems technology............	4,800	4,900	3,904	5,100

OBJECTIVES AND STATUS

The objective of this program is to advance the integrated technologies of aeroacoustics and high speed configurations. The program is significantly increasing emphasis on high-speed research for promising opportunities of tiltrotor configurations.

In 1990, the NASA-developed comprehensive noise prediction code called ROTONET added an empirically designed module to address blade-vortex interaction noise. Validation of the code continues with industry to meet the prediction accuracy goal of 1.5 decibels. To meet a goal of 80 percent noise reduction, industry was solicited for novel ideas with five areas chosen for promise.

In preparation for increased high-speed rotorcraft research, tiltrotor noise is being measured and the results analyzed to determine abatement profiles for civil operation and to address detection for military use. Advanced composite blades for the XV-15 tiltrotor research aircraft are in flight testing to evaluate their promise for increased maneuverability, performance, and reduced noise. Tiltrotor wind model tests are proceeding in small scale with the goal of download reduction which will significantly increase payload capabilities. Studies are underway to assess the economic and operational viability of civil application of the tiltrotor.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects reduction of $1.0 million, $0.3 million for the general reduction and $0.7 million due to sequestration.

BASIS OF FY 1991 ESTIMATE

In noise technology, far-field propagation and detection prediction are two acoustics activities to be investigated for military use. Validation of ROTONET for new concepts will continue. In the high-speed rotorcraft area, the XV-15 tiltrotor will fly certification profiles for noise abatement, failure modes, and handling qualities. A high speed concept called the trailed tiltrotor will be tested in low and high speed to evaluate drag and flutter. Download concepts will be examined analytically and in ground tests.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
High-performance aircraft systems technology	11,000	9,900	9,691	10,500
High-speed research	--	25,000	--	--
Total	11,000	34,900	9,691	10,500

OBJECTIVES AND STATUS

The objective of this program is to generate validated engineering methods and design data applicable to the development of advanced high-performance, high- speed aircraft applications. The program objectives are accomplished by analysis, ground-based simulations, wind tunnel experimental research, and flight research involving tests of advanced aircraft concepts and systems.

The F-18 high angle-of-attack research vehicle has been extensively instrumented and is being modified to include a thrust vectoring control system with the goal of obtaining a flight-validated data base for the validation of Base R&T design methods for highly agile aircraft. The thrust vectoring control system has a design goal of enabling controlled flight to higher angles-of-attack than previously tested. The F-15 highly integrated electronics control (HIDEC) project, has completed an assessment of advanced trajectory guidance and control algorithms and an evaluation of the maintenance diagnostic software to be used in the self-repairing flight control system tests. The F-106 vortex flap flight experiment has completed flight testing with a flap position of 40 degrees. Flight tests of a 30 degree deflection will be conducted to conclude this flight activity which will enable an assessment of the predicted improvements in takeoff, landing, and maneuvering performance that can be achieved from a vortex flap. The second X-29 aircraft has been delivered to NASA and flight tests have begun to assess the high angle-of-attack characteristics of the unique forward-swept wing configuration. Two F-16XL aircraft were obtained from the Air Force, and exploratory research has been initiated to assess the feasibility of achieving significant laminar flow on highly swept wings of civil and military aircraft at supersonic speeds.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $25.2 million. This reflects a $0.2 million reduction in flight research to accommodate the general reduction and the realignment of the high-speed research program to a separate line as a result of its importance and increasing research emphasis.

BASIS OF FY 1991 ESTIMATE

The flight research activity will involve several high-performance aircraft tests designed to investigate advanced concepts. Flight research will be initiated using the F-18 high angle-of-attack research vehicle (HARV), which has been modified with the addition of a multi-axis thrust vectoring system to provide for controlled flight at high angles of attack. The assessment and characterization of forward-swept wing performance, flying qualities, and maneuverability at high angle-of-attack will be completed. Flight evaluation of a control system that will provide additional aircraft performance will be initiated. Flight tests of a self- repairing flight control system design, developed jointly with the Air Force to improve system failure detection and reliability, will be completed on the F-15 aircraft during this period. Computational design tools will be utilized to design supersonic laminar flow experiments which will be tested and evaluated on the F-16XL aircraft. The flight data will be used to improve and validate these tools. Flight research utilizing a YAV-8B Harrier, modified with a digital electronic control system, will be initiated to investigate a broad range of flight and propulsion control integration technologies developed in the flight systems program for short takeoff and vertical landing aircraft.

		1990		1991
	1989 Actual	Budget Estimate	Current Estimate	Budget Estimate
		(Thousands of Dollars)		
Advanced propulsion systems technology..	13,952	14,500	14,152	15,000

OBJECTIVES AND STATUS

The objective of this program is to explore and exploit advanced technology concepts for future aircraft propulsion systems.

Activities in the advanced turboprop systems program are devoted to establishing concept feasibility and providing the broad analytical and experimental data base necessary for achieving the concept's full potential. Research using the propfan test assessment aircraft was completed in 1989. The aircraft was used to obtain steady and unsteady propeller blade surface pressure measurements for both Euler and Navier-Stokes code validation, as well as an extensive enroute noise data base in cooperation with the Federal Aviation Administration. The analytical models developed of airborne and structureborne noise

contributions to the cabin environment underwent initial validation in both industry and NASA sponsored flight tests. Research in 1990 to improve propulsive efficiency will include development of a three-dimensional Euler analysis capability for ducted propellers, wind tunnel tests of advanced ducted propeller models for aerodynamics, acoustics and installation aerodynamics, the final flight verification of interior noise prediction and control technology and an in-depth analysis of the enroute noise data base acquired using the propfan test assessment aircraft to determine the effects of the atmosphere on aircraft-to-ground noise propagation.

In the general aviation/commuter engine systems technology program, the objectives are to raise the performance level of small turbine engines to approximately that of large transport turbine engines with a decrease in fuel consumption of 30 percent. Research continues on radial flow turbomachinery to reduce the impact of small components on propulsion system efficiency. The work is focused on providing a detailed understanding of the design parameters that affect component performance through the development of analytical codes and the associated experimental data base for verification. An experimental evaluation of a compact radial inflow turbine yielded improved efficiency in a turbine that was 40 percent shorter. In 1990, advanced analytical codes will be used to evaluate the viscous effects in the compact turbine and a centrifugal compressor in preparation for experiments to obtain detailed high-speed flow field data to determine the capability of the codes to predict compressibility effects. In addition, experimental research will be initiated to evaluate high temperature composite materials for combustor liners.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $0.3 million in the advanced turboprop area for sequestration.

BASIS OF FY 1991 ESTIMATE

The emphasis in advanced turboprop systems research will be on advanced unducted and ducted concepts, high bypass propulsion/airframe installation aerodynamics, and the development of improved aerodynamic and structural analysis techniques for both unducted and ducted high bypass subsonic propulsion systems. Short, thin nacelles for ducted propeller propulsion systems will be evaluated to determine efficiency and capability to operate at high angle-of-attack. Unducted configurations with increased sweep will be evaluated for reduced noise and improved performance. Wing- and aft-mounted unducted propulsion system installations designed for minimum interference drag will be evaluated to determine maximum performance potential and to develop a code validation data base. Analytical research will include the coupling of three-dimensional unsteady Euler code with advanced structural codes to obtain an improved capability to predict unducted and ducted aeroelastics. The same approach will be used, i.e., coupling of aerodynamic, structural and acoustics, to provide an advanced capability to predict source noise.

The general aviation/commuter engine technology effort will continue to demonstrate component improvements through the practical application of validated analysis codes that will enable high-performance small engine systems. In support of combustor research, a three-dimensional Navier-Stokes two-phase, reacting-flow code will be developed. For turbomachinery, experimental results will be used to validate and improve analytical capability to predict aerodynamics and heat transfer in cooled radial turbines and viscous flows in high-speed centrifugal compressors.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Numerical aerodynamic simulation.........	25,927	28,500	27,798	29,600
NAS operations...........................	13,758	14,000	14,000	14,500
Total....................................	39,685	42,500	41,798	44,100

OBJECTIVES AND STATUS

The numerical aerodynamic simulation (NAS) program goal is to develop a preeminent capability for numerical simulation of aerodynamic flows. Ongoing research and technology base efforts in computational aerodynamics benefit significantly from the advanced computational capabilities to be provided by the NAS program. This program provides the computational capabilities required to obtain solutions to problems which are currently intractable. The combination of these programs will provide pathfinding aeronautical research for the future, allowing solutions of the full Navier-Stokes equations and enabling the prediction of performance of complex aircraft geometries. To meet this goal, the NAS program is pursuing the following objectives: (1) acquire pathfinding, state-of- the-art, high-speed processors; (2) provide a uniform, user-friendly system with equivalent capabilities for local and remote users; (3) provide an auxiliary processing center for secure processing; (4) investigate and incorporate parallel architecture machines into future generations of the NAS; (5) provide a hardware and software development environment for prototyping and testing of computers, networks, storage devices, workstations, and graphic output devices; and (6) continue to research and develop an increasingly sophisticated system of hardware/software tools and environment to assist the user in performing CFD tasks and to improve productivity.

Two high-speed processor generations, HSP-1, a Cray 2 supercomputer, and HSP-2, a Cray YMP supercomputer, have been integrated into the system in the NAS facility. The Cray YMP is four times faster than the Cray 2 and represents the newest advances in supercomputer technology. NAS was the first site to install the new Cray YMP with delivery in the last quarter of FY 1988 and test and integration completed in the first half of FY 1989. HSP-1 was upgraded to a newer model Cray 2 and the original Cray 2 has been dedicated to classified processing in the new auxiliary processing center. In keeping with the NAS objective to incorporate state-of-the-art improvements, a new generation supercomputer, HSP-3, with four times the performance of HSP-2, will be acquired. When HSP-3 is fully integrated into the NAS system, HSP-1 will be removed.

The NAS system provides a Unix operating system on all levels of the system from the supercomputer to the workstation. With high-speed communication links, remote users are provided an environment which is equal to local, on-site users. The NAS system is currently supporting over 1350 users on 458 projects at over 120 sites.

To keep pace with increased supercomputer capability, a new higher performance, Unix-based mass storage software system has been completed and integrated into the NAS system. The local data network has been upgraded and new advanced workstations have been acquired. Operating systems, network, compiler, and other software systems have been upgraded in performance and functionality.

Several applied research and advanced development efforts are underway to support the goal for NAS. This program provides the capability to exploit new computer technologies for CFD and related applications, evaluate commercial products, provide industry with future product requirements, and design new systems and software. Research and development projects are being conducted in high-speed networks, mass storage systems, scientific visualization and massively parallel computing. A 64,000 node Connection Machine-2 has been integrated into the NAS system for use in parallel algorithm and application software research. Studies into advanced computer architectures for future incorporation into NAS will continue with exploration of highly parallel multiprocessor systems. Research into advanced techniques for user interface and scientific visualization software for complex steady and unsteady flow simulations is being conducted and prototype software is being developed on newly acquired advanced workstations. Implementation of a very high-speed network prototype is underway which is targeted at increasing network data rates by two orders of magnitude.

<u>CHANGES FROM FY 1990 BUDGET ESTIMATE</u>

The current estimate reflects a reduction of $0.7 million in peripheral equipment and workstations as a share of the general reduction.

BASIS OF FY 1991 ESTIMATE

The Numerical Aerodynamic Simulation (NAS) system will continue its nationwide operation supporting over 1000 users within NASA, DOD, other government agencies, industry and academia. The third high-speed processor will be acquired and incorporated into the NAS system. Higher performance mass storage hardware, using the software introduced in FY 1990, will be integrated into the NAS system to accommodate the increased performance capabilities provided by HSP-3. A new local high-speed network, based on current prototype development, will be deployed and the remote network upgraded with new gateway hardware and software. User interface and scientific visualization software now under development will become operational. To meet the challenge of providing increased operational computing capability for aerospace applications, pathfinding research will continue in parallel architectures and algorithms with mapping of specific aerodynamic simulation problems onto advanced computational platforms. Operating, user interface and visualization software research will continue with emphasis on the incorporation of expert systems and distributed systems technology. System research and prototyping will be conducted to provide improved capabilities for simulation set-up and result analysis. The principal objectives are to improve configuration geometry and computational grid generation and to interactively perform analysis on very large unsteady flow solution databases in an efficient manner.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
High-speed research......................	--	--	24,494	44,000

OBJECTIVES AND STATUS

Studies have indicated that, under certain economic conditions with sufficient technology development, future high-speed aircraft could be economically competitive with long-haul subsonic aircraft. Currently, however, critical environmental concerns about atmospheric impact, airport noise, and sonic boom present powerful disincentives to the private sector to pursue such research and technology. The high-speed research program will address the resolution of these barrier environmental issues and develop the basis for evaluating technology advances that can provide the necessary environmental compatibility.

In collaboration with researchers at other agencies, universities and in the private sector, research will be conducted to address atmospheric effects including depletion of ozone, perturbations to atmospheric chemistry on a global scale and the potential for long-term climate change. Theoretical models of the atmosphere will be developed and applied using laboratory and in-flight measurements to reduce the large uncertainties in current predictions. During FY 1990, a range of fleet scenarios is being applied to two-dimensional global models using homogeneous, gas-phase chemistry. Work has begun on development and

application of three-dimensional models with consideration of heterogeneous chemistry, along with laboratory measurements of the chemical kinetics and definition of aircraft-based measurement requirements. Aircraft system studies will also be conducted to provide a framework for related technology efforts by determining the impact of environmental requirements on the vehicle and by investigating the commercial viability of proposed technology solutions. In this manner, key technology needs will be identified and the overall program plans adjusted accordingly. During FY 1990, engines are being evaluated for later aircraft installation studies. Aircraft configurations are being evaluated for low sonic boom and for synergistic environmental and economic benefits of high-lift aerodynamics and supersonic laminar flow control.

The emissions and source noise research will provide the technology base for reduced engine emissions and exhaust noise by developing improved analytical models, by performing laboratory scale experiments, and by testing engine-level components to confirm feasibility of meeting environmental goals. During FY 1990, the research emphasis will be placed on prediction codes and comparison of analytical results with results of fundamental experiments. Emissions measurements will include flowfield mapping of a rich/lean combustor concept, evaluation of an advanced airblast fuel injector for low nitrous oxide (NOx) combustors and NOx destruction additives. Source noise research will include laboratory experiments with inverted velocity profiles for co-annular jets and nonround nozzle geometries, as well as static and wind tunnel testing of one candidate nozzle configuration.

Community noise and sonic boom studies will be conducted with the objectives to demonstrate that takeoff and landing approach noise can be reduced to FAR 36, Stage III levels, and to minimize sonic boom impact. Achieving the airport noise objective requires the development of accurate system noise reduction methodologies and advanced high-lift systems, as well as evaluation of engine placement effects and optimization of landing and takeoff procedures. Sonic boom research will establish human acceptability criteria and develop low-boom concepts and predictive methodologies. Laminar flow control research will also be conducted because of its strong favorable impact on aircraft and engine size and, therefore, noise. During 1990, the inclusion of a new supersonic jet noise module into the system noise code is being initiated and some preliminary screening of high-lift concepts completed. Baseline sonic boom wind-tunnel tests are to be conducted and the results used to develop prediction codes.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The high-speed research program has been separately identified as a new element as a result of its importance and increasing research emphasis, and the funding ($25.0 million) was realigned from the high-performance aircraft systems technology program. The high-speed research program has been reduced by $0.5 million in the areas of atmospheric effects, emissions and source noise, and community noise and sonic boom to accommodate the general reduction.

BASIS OF FY 1991 ESTIMATE

The FY 1991 program provides for preparations for flight testing to support the atmospheric studies, for more detailed consideration of alternate propulsion systems, and increased emphasis on experiments concerning reduced emissions, noise and sonic boom. A primary goal of the atmospheric effects studies will be to evaluate accuracy and uncertainty in global atmospheric assessment. Research studies will be conducted using three-dimensional models for dispersion and mixing of emissions and detailed two-dimensional heterogeneous chemistry. Laboratory measurements of critical rates for heterogeneous reactions in the background atmosphere will be completed, and instrumentation development conducted for atmospheric measurements. Ongoing system studies will culminate in the selection of the two best propulsion concepts resulting from aircraft installation considerations. Benefits of supersonic overland flight will be evaluated, and long-lead technology for supersonic laminar flow control will be defined.

Assessment of high-lift systems that promise reduced noise will continue, along with other advanced aerodynamic concepts that enhance economic viability and environmental compatibility.

In the emissions and source noise area, emphasis of the emissions research will be on low NOx concept verification experiments and continuing improvements in analytical capability, while the source noise research will shift to increased screening of concepts that have the potential to meet reduction goals. Combustor emissions flame tube tests will be used to evaluate low NOx techniques, with data also being used to verify prediction codes. Advanced concepts screening will be initiated to define low-emission combustor components. Laboratory level acoustics experiments will be conducted to provide a code validation data base for new jet plume shock and rapid mixing methodologies that promise improved source noise reduction capability. Performance and acoustics will be evaluated experimentally in low-speed and high-speed wind tunnels for nozzle concepts at subscale using high-temperature exhaust flows. Concepts to be evaluated include the reference conical, dual-flow axisymmetric, hypermixer and the naturally aspirated co-annular nozzles.

A preliminary screening of advanced high-lift concepts which affect system noise will be completed, and community noise prediction capability for supersonic aircraft will be incorporated into system noise codes. A subjective assessment of the effects of sonic booms will be made and near-field computational techniques developed to assist evaluation of aerodynamic configurations.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Transatmospheric research and technology.	69,400	127,000	59,027	119,000	RD 13-2

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Ames Research Center	4,550	5,000	5,000	3,000
Langley Research Center	10,493	9,000	21,600	7,000
Lewis Research Center	6,060	6,000	9,400	5,000
Headquarters	48,297	107,000	23,027	104,000
Total	69,400	127,000	59,027	119,000

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OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

OBJECTIVES AND JUSTIFICATION

The transatmospheric research and technology program is a portion of the joint NASA/Department of Defense (DoD) National Aero-Space Plane (NASP) program. The program objective is to develop and then demonstrate, in an experimental flight vehicle, the technology required to permit the nation to develop reusable, single-stage-to-orbit (SSTO) vehicles with airbreathing primary propulsion and horizontal takeoff and landing.

The program was revised and rescheduled in the summer of 1989, based on the President's endorsement of the National Space Council's recommendations to extend the second, current phase of the program, which focuses on technology development. Important work remains in propulsion, materials and structures, controls, and applications of computational fluid dynamics. Emphasis is also placed on integrating these technologies into vehicle concepts to assess both vehicle and technology potential. A decision in the second quarter of FY 1993 will determine whether to proceed to Phase 3, which consists of designing, constructing and flight testing an experimental flight vehicle, the X-30.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $67 million as a result of direct Congressional action on the FY 1990 budget. A further reduction of $1.0 million was applied to meet sequestration for total NASA funding of $59 million. The Department of Defense will provide $194 million to the program for total NASP funding of $253 million in FY 1990.

BASIS OF FY 1991 ESTIMATE

The FY 1991 NASP program will continue the full spectrum of technology development. Contracted studies will proceed on vehicle-concept development studies for the X-30, on major systems, and on systems components. The vehicle-concept studies will reflect results of prior studies on various combinations of Phase 3 flight and ground tests that can accomplish the NASP mission with the lowest costs and risks. Vehicle conceptual development will still be the responsibility of the airframe contractors (currently General Dynamics, McDonnell Douglas, and Rockwell International). The systems work by the airframers will

include designing, fabricating and testing structural components, such as actively cooled structures and large wing/fuselage panels. The engine contractors (currently Pratt & Whitney and Rocketdyne) will continue to develop fully integrated engine concepts that must function in several very different modes as the X-30 accelerates to reach orbital speed. Engine development will progress from component tests to the design and fabrication of ground test engines.

Efforts to reduce the number of configurations under study are expected to lead to either a teamed effort by the existing set of contractors or a team of one airframe and one engine company. This will focus the total program and facilitate efficient execution of more detailed work.

The technology maturation plan (TMP) segment of the NASP program covers a large array of high-risk, enabling technology tasks in selected discipline areas. It is conducted by NASA, other government agencies and contractors; results are rapidly disseminated to the NASP program participants. Materials development and characterization will continue to be a significant part of this effort. The list of advanced, high-temperature materials being worked includes advanced carbon-carbon with special coatings and a set of titanium-aluminide alloys with and without fiber reinforcement. The applications include tankage requiring reduced sensitivity to hydrogen embrittlement and regeneratively cooled engine components.

An extensive activity to develop computational fluid dynamics (CFD) tools and correlate results of their applications with experimental data will continue. The CFD methods are providing improved three-dimensional analysis capabilities for both internal and external flows and even "real gas" effects at flow conditions beyond Mach 12.

Propulsion research and development will lead toward the testing of ground test engines. Lower speed work (at Mach numbers of 0 to 6) will continue to address component performance and component/vehicle integration. The focusing of airframe-engine conceptualization will allow more detailed and sophisticated integration of the propulsion and airframe with special tests of the effects of airframe forebody and inlet and nozzle geometries. Efforts at the higher Mach numbers are directed at scramjet concepts. Refined analyses of combustor flows will treat both the controlling physical and chemical phenomena; correlation of theoretical, CFD and experimental studies will lead to enhanced performance. Performance/penalty tradeoffs will be assessed over the entire operating range of the vehicle.

Aerodynamic experiments covering flows from Mach 0 to 25 will be conducted for the more mature vehicle concepts from the focused efforts of the industry and government teams. New methods of predicting the transition of boundary-layer flows to the turbulent condition (with greater heat transfer and drag) will be developed and correlated with test data.

Fuel studies will provide improved insight into the production, storage and utilization of slush hydrogen, a mixture of solid and liquid hydrogen. The significant increase in thermal capacity of slush over liquid hydrogen enhances vehicle performance but continues to provide challenges in terms of both overall thermal management and systems design for materials compatibility and high performance.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — SPACE RESEARCH AND TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and technology base	124,100	130,100	124,961	125,700	RD 14-5
Civil space technology initiative (CSTI) program	121,800	144,500	123,810	171,000	RD 14-31
Exploration technology program	40,000	47,300	26,900	179,400	RD 14-35
In-space technology experiments program	--	16,200	10,200	19,800	RD 14-39
Total	285,900	338,100	285,871	495,900	

Distribution of Program Amount By Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	15,280	16,400	13,050	20,100
Kennedy Space Center	680	700	1,427	1,400
Marshall Space Flight Center	42,104	66,000	58,465	110,300
Goddard Space Flight Center	8,580	9,800	10,898	9,800
Jet Propulsion Laboratory	40,231	49,400	34,645	63,600
Ames Research Center	28,858	33,400	27,895	43,400
Langley Research Center	55,063	58,700	48,607	67,300
Lewis Research Center	60,873	66,600	54,385	111,800
Headquarters	34,231	37,100	36,499	68,200
Total	285,900	338,100	285,871	495,900

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — SPACE RESEARCH AND TECHNOLOGY

OBJECTIVES AND JUSTIFICATION

The overall goal of the space research and technology program is to provide advanced, enabling technologies, validated at a level suitable for user-readiness, for future space missions in order to ensure continued U.S. leadership in space to meet national needs. To achieve this goal, a commitment is required to provide a broad base of advanced technology for vehicle and subsystems concepts, components, devices, and software; to develop technical strengths in the engineering disciplines within NASA, industry, and academia; and to perform critical technology validations that facilitate the transfer of new technology with a high level of confidence to future space missions.

The space research and technology program consists of two basic program areas, the research and technology base and focused programs. The objective of the research and technology base program is to gain a fuller knowledge and understanding of the fundamental aspects of phenomena in critical disciplines. Within the research and technology base program, high-leverage technological advances and concepts are brought to the level of demonstrating proof of principle. The base program is the seedbed for generating the more highly mission-focused technology programs.

Focused programs, based on requirements provided by the potential users of the technology, develop technology for specific future applications and deliver products in the form of proven hardware, software, and design techniques and data. Three focused programs are currently underway, the Civil Space Technology Initiative (CSTI), the Exploration Technology program, which encompases the previous Pathfinder program, and the In-Space Technology Experiments Program (IN-STEP). The CSTI program is a positive first step to restore the agency's technical strength and provide options for future Earth orbit, high-priority civil space goals. CSTI is developing technologies to enable efficient, reliable access to Earth orbit; enhance operations in Earth orbit; and increase the effectiveness of science missions from Earth orbit. The exploration technology program contains activities from the former Pathfinder program which have been reoriented in FY 1990 and augmented in FY 1991 toward the goals of the Exploration Technology program. It is a vital element of the national space policy, and is developing critical capabilities to enable missions, both human and robotic, to expand human presence and activities beyond Earth's orbit into the solar system. It will push U.S. technology forward through a strong partnership between NASA, industry, and

universities. This is a portion of the President's Human Exploration Initiative (HEI) which is discussed in the Agency Summary section. Proof-of-concept testing for mission-critical engineering designs will be an important product of the CSTI and exploration technology programs and will directly support the continuing evolution and maturation of mission plans. An important element in accomplishing the OAST goal is the development of selected space technology experiments for flight validation. The in-space technology experiments program will develop key flight experiments to provide valuable information for solving critical technology problems.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The Space Research and Technology program has been reduced by a total of $52.2 million. This includes Congressionally directed reductions of $6.0 million in the in-space technology experiments program, $17.5 million in the Civil Space Technology Initiative (CSTI) program, and $20.4 million in the exploration technology program. In addition, the Research and Technology Base has been reduced by $4.6 million as part of the general reduction. The sequestration effects resulted in a reduction of $3.7 million, $0.5 million in the research and technology base and $3.2 million in the CSTI program.

BASIS OF FY 1991 ESTIMATE

In FY 1991, the research and technology base program will continue to explore newly emerging areas that offer longer range, high-leverage program benefits. The research and technology base program consists of ten discipline elements: aerothermodynamics, space energy conversion, propulsion, materials and structures, space data and communications, information sciences, controls and guidance, human factors, space flight, and systems analysis. In addition, the university space research program, supported by the research and technology base, will conduct research in critical areas and continue to enhance and broaden the capabilities of the nation's academic community to participate more effectively in the U.S. civil space program. The narratives that follow discuss in greater detail highlights of FY 1990 accomplishments and planned FY 1991 activities.

The objectives of the CSTI program are focused on research in three broad categories -- transportation, operations, and science technology. The research is targeted at opportunities with clearly defined end objectives to validate technology advances. Specific program elements are: automation and robotics, propulsion, power, information technology, large structures and control, and vehicle technology.

The exploration technology program, major segments of which were begun in FY 1989 under the Pathfinder program, will continue building a broad set of technologies to enable future robotic or manned solar system exploration missions. The exploration technology program is divided into eight major thrusts: space transportation, in-space operations, surface operations, human support, lunar and Mars science, information systems and automation, nuclear propulsion, and innovative technologies and systems analysis.

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The in-space experiments technology program is an important new program, begun in 1990, designed to develop key flight experiments to provide validated, advanced space technologies for improving the effectiveness and efficiency of current space systems and to provide major advancements for future systems. Previous efforts over the past few years have identified advanced, highly innovative technology concepts that require testing or validation in the actual space environment in order to obtain data that cannot be acquired in ground-based laboratories, to reduce the risk to the potential users which will increase the rate of transfer of advanced technologies into future space missions, and to begin to prepare for conducting technology experiments using Space Station Freedom.

RESEARCH AND TECHNOLOGY BASE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Aerothermodynamics research and technology	9,938	10,500	11,663	11,100	RD 14-6
Space energy conversion research and technology	12,500	12,900	12,900	12,800	RD 14-8
Propulsion research and technology	13,917	15,200	14,380	13,800	RD 14-10
Materials and structures research and technology	20,525	21,600	16,200	16,000	RD 14-13
Space data and communications research and technology	8,387	8,800	8,900	8,900	RD 14-16
Information sciences research and technology	7,158	7,500	7,400	15,100	RD 14-18
Controls and guidance research and technology	5,495	5,600	5,432	4,700	RD 14-21
Human Factors research and technology	4,340	4,600	4,600	3,900	RD 14-23
Space flight research and technology	18,686	19,400	20,361	15,500	RD 14-25
Systems analysis	6,944	6,900	6,025	6,200	RD 14-27
University space research	16,210	17,100	17,100	17,700	RD 14-29
Total	124,100	130,100	124,961	125,700	

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Aerothermodynamics research and technology.........................	9,938	10,500	11,663	11,100

OBJECTIVES AND STATUS

Future aerospace vehicles, such as aeroassist space transfer vehicles (ASTV) aerospace planes, and hypersonic cruise and maneuver vehicles, must be capable of sustained hypervelocity flight in both rarefied and continuum flow regimes. The design of these vehicles presents formidable challenges to current prediction methodologies. To meet these challenges, this program is pursuing the following objectives: (1) development and application of advanced computational methods and numerical techniques covering the entire spectrum of continuum, transitional, and rarefied flows; (2) development of accurate and detailed real-gas chemistry and high-speed turbulent flow models and the efficient integration of these models with standard computational flow codes; (3) establishment of a high-quality ground and flight experimental data base for code validation and verification; (4) direct correlation and comparison of computations with available ground and flight data; (5) establishment of a detailed aerothermal loads data base and development of fully integrated analysis techniques; and (6) enhancement of engineering design codes and advanced configuration analysis capability to support rapid evaluation of future vehicle/mission concepts.

Progress continues to be made in the development of computational fluid dynamics (CFD) codes for simulating hypervelocity rarefied flowfields. In addition to the ongoing work with the direct simulation Monte Carlo techniques, a newly developed, highly efficient particle kinetic simulation scheme--which is based on new algorithm concepts using massive high-speed computer memory and higher order molecular collision models--has been developed to simulate high-altitude, low-density nonequilibrium hypersonic flows of diatomic gases. Application of these schemes will be extended through the transition regime toward the continuum regime.

In addition to the development of these particle kinetic simulation schemes, new efficient schemes for low-density hypersonic flows in thermochemical nonequilibrium are being pursued. These schemes use newly developed constitutive relations and slip conditions that will permit extension of continuum-based methodologies for real-gas Navier-Stokes simulation into the rarefied regime.

Complementary to the development of computational fluid dynamics (CFD) codes and numerical simulation capability is the requirement to establish a high-quality aerothermodynamics experimental data base applicable to a wide range of vehicles and flow conditions. In addition to the aerodynamics and aerothermodynamics data bases being developed in conventional wind tunnels, data are being obtained from ballistic ranges, shock tubes, and high-velocity flight programs for use in validating CFD codes with real-gas features.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This program has been increased by a total of $1.2 million. Increased computer usage required a realignment of $3.0 million from other research and technology base programs, which has been offset by a decrease of $1.8 million in generic hypersonic research as part of the general Congressional reduction and sequestration.

BASIS OF FY 1991 ESTIMATE

The FY 1991 program in computational methods will continue to emphasize techniques for efficient coupling of real-gas chemistry models to Navier-Stokes flowfield codes. This will involve the development of more sophisticated chemistry models--based on computational chemistry results--and more robust and computationally efficient solution algorithms. Work will also continue on the development of more easily used adaptive grid generation techniques, which can be applied to a variety of flowfields and configurations. These improved capabilities will permit more accurate simulation of continuum flow around advanced space transportation vehicles under both ascent and entry conditions.

In the area of direct simulation techniques, the emphasis will continue on developing and applying the highly efficient particle kinetic simulation method. Results from this method will be compared with benchmark results from the more computationally intensive Monte Carlo method to determine the range of application for the more efficient particle kinetic simulation method. The particle kinetic simulation model holds great promise for enabling rapid parametric studies of maneuvering vehicles in the upper atmosphere.

Expansion of the current aerothermodynamic experimental data base will continue, with emphasis being given to experiments aimed at code calibration and validation. Specifically, experiments will be aimed at providing nonequilibrium flows around a variety of configurations. To this end, use of NASA's high-enthalpy/high-velocity ballistic ranges and shock tubes will be increased and the development of nonintrusive diagnostic measurement techniques for hypersonic flow will be actively pursued to enable more accurate and informative hypersonic experimentation in ground facilities.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space energy conversion research and technology	12,500	12,900	12,900	12,800

OBJECTIVES AND STATUS

The objective of this program is to develop technology alternatives that improve performance, reliability, and cost effectiveness of space power both for manned and unmanned space operations, including autonomous Earth-orbiting and planetary exploration spacecraft. To meet the challenge, improvements of a factor of two to five and increased life potential are being sought in various solar power generation components, chemical energy conversion systems, energy storage systems, electrical power management and distribution, as well as thermal management systems. For spacecraft photovoltaic technologies, the goal is to improve the total system performance enough to permit a 50 percent increase in payload mass, while not increasing the spacecraft overall mass. For environmental control and life support systems, the goal is to provide a technology base in chemical processing techniques to support future human space missions.

Recent developments in the photovoltaic (solar power) area include: a 22 percent efficient gallium arsenide concentrator solar cell which can be coupled to a domed mini-Fresnel lens to double or triple the specific power of radiation-resistant arrays; and, testing of radiation-resistant indium phosphide solar cells which have yielded 18 percent efficiency; and, a twofold improvement in solar panel specific power to over 130 watts per kilogram.

NASA's Lewis Research Center received a "Research & Development 100" award in 1988 for demonstrating long-lived nickel-hydrogen battery performance for low Earth orbit applications. Lewis has extended this work to flight-weight cells and is designing lighter weight batteries. This battery has about ten times the cycle lifetime of existing flight systems, such as those to be used on Space Station Freedom and on the Hubble Space Telescope. Research on advanced rechargeable batteries, such as lithium-titanium-disulfide, has demonstrated in laboratory-scale tests the potential for achieving 80 watt hours per kilogram which is about four times current capabilities. NASA's Jet Propulsion Laboratory has begun fabrication of lightweight electrodes. JPL has also built and tested a recirculating test cell for the alkali metal thermoelectric converter (AMTEC).

Advanced solar dynamic concentrator technology, with only 25 percent of the mass per unit area of those proposed--but not yet approved - to be flown on Space Station Freedom, is being investigated, and thermal receiver concepts with one-half the mass of those proposed for Space Station have been identified.

BASIS OF FY 1991 ESTIMATE

In spacecraft photovoltaic technologies, functional testing will be completed on a lightweight prototype array wing involving 12 panels. The long-term goal is a solar array with 300 watts per kilogram that can withstand launch and on-orbit environments. Such specific power is about five times better than the best that has been flown. Research will continue on developing 20 percent efficient indium-phosphide solar cells which can withstand high radiation environments such as those in the Van Allen radiation belts around Earth and in the radiation belts around Jupiter.

Critical technology experiments initiated on two advanced solar dynamic receiver concepts (one based on the Stirling cycle, the other based on the closed Brayton cycle) and the demonstration of lightweight, highly accurate solar concentrator technology is underway. Planned advancements in this area will result in a factor of three improvement in the specific power of solar dynamic power systems. Analyses of current thermal energy storage systems will be completed and work started on thermal energy storage materials for testing on an eventual flight experiment. Materials with high thermal conductivity and high heat of fusion are needed to develop efficient and lightweight thermal energy storage systems and receivers.

Work will continue on extending the performance of lithium-titanium-disulfide batteries to reach a 1000-cycle lifetime, which would make such a battery suitable for future planetary missions, and on conducting advanced nickel-hydrogen battery cell tests,leading toward the goal of 100 watt hours per kilogram, which is about five times greater than the current state of the art.

Experimental and analytical efforts to study droplet formation, heat transfer mechanisms and zero-gravity phase change, and fluid flow phenomena will be conducted to evaluate materials and designs and develop the required technology base for advanced thermal management concepts that will allow the large amounts of heat generated by high, medium, and low power systems to be dissipated. High-frequency power system designs and components will be developed to reduce the weight, increase the life, and meet the space radiation and temperature constraints. Experimental power systems, biased to simulate space charging effects, will be tested in vacuum chambers to determine the possible detrimental effects of high-voltage arcing and to develop designs which will be suitable for use in civil missions.

Research will continue on developing efficient air, water, and waste processing technologies, sensor and monitoring instrumentation and controls technology for air and water quality, as well as the development and validation of computerized simulation techniques to support and guide the research effort.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Propulsion research and technology.......	13,917	15,200	14,380	13,800

OBJECTIVES AND STATUS

The objectives of this program are: to develop and validate accurate analytical simulations of the chemical and physical processes that occur in space propulsion systems; and, to evaluate the potential benefits and feasibility of advanced concepts that will improve our propulsion capabilities well beyond those that are achievable with today's operational systems. Included are propulsion systems for advanced transportation systems and for planetary ascent vehicles. Also included is the Earth-orbiting satellite auxiliary propulsion system needed for such functions as attitude control and station-keeping. Finally, a part of the program is dedicated to the identification and evaluation of very high-energy advanced propulsion concepts that, if proven feasible and ultimately practical, would provide a quantum leap in propulsion capabilities that could be applied to a number of the above applications.

Advanced transportation propulsion technology is directed toward the continued expansion of fundamental knowledge and understanding of rocket engine processes and principles and toward advanced concepts leading to more efficient and effective component and engine systems that will provide enhanced payload delivery capability for future space transportation vehicles. Fundamental efforts are focused on the development and experimental verification of combustion instability codes, unified computational fluid dynamics codes, models for internal flows and turbomachinery, soft seal rub dynamic models, and fluid dynamic processes in combustion chambers and nozzle boundary layers. Considerable progress has been made in development of analytical representation of these phenomena. Experimental verification of these analytical models and techniques remains to be accomplished. Advanced concept efforts concentrate on promising design concepts and high energy density propellant combinations to provide enhanced propulsion system performance.

Emphasis in combustion research is on metallized gelled propellants, compliant thrust chamber fabrication techniques, and high-temperature (4000 degrees Fahrenheit) combustor materials. The flow and ignition characteristics of gelled hydrocarbon fuels, metallized with aluminum, have been successfully established.

Lunar/planetary propulsion technology is directed toward the evaluation of propulsion concepts utilizing planetary in-situ propellants to reduce Earth launch vehicle requirements for future space exploration missions. Experimental studies are focused on the safety and handling features, rheological properties, combustion and cooling characteristics of an oxygen and aluminum monopropellant that could be obtained from the lunar soil, as well as the combustion physics of oxygen and carbon monoxide that could be obtained from the Martian atmosphere.

Auxiliary or low-thrust propulsion technology is directed toward improved capabilities in resistojets, arcjets, ion thrusters, magnetoplasmadynamic (MPD) thrusters, and long-life, efficient gaseous and storable liquid chemical propellant rockets. In fiscal year 1991 the low-thrust program will focus on the following elements: (1) building of iridium-coated rhenium thrusters in the range of 20 to 800 newtons and demonstrating dual mode operation of space storable propellants with increased performance in specific impulse to approximately 340 seconds; (2) demonstrating life and performance of 2-5 kilowatt arcjets with increases in specific impulse in excess of 550 seconds; and (3) completion of a 500-hour, 10-kilowatt ion engine life test.

Advanced propulsion concepts studies continue to investigate promising capabilities not yet within our reach. Efforts include conducting selected critical experiments and analytical evaluations of nuclear, high-energy chemical, and advanced propulsion concepts. A magnetically confined microwave-induced plasma experiment has been initiated at the Massachusetts Institute of Technology as the first experimental effort under the advanced concepts program.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This program has been reduced by $0.8 million. This includes $0.5 million in advanced propulsion concepts and in low thrust primary and auxiliary propulsion resulting from sequestration and a $0.3 million reduction in computer usage. The $0.3 million was realigned to the aerothermodynamics research and technology program.

BASIS OF FY 1991 ESTIMATE

In 1991, a propulsion evaluation system for advanced transportation vehicles will be implemented to better assess the potential payoffs of technology improvements to propulsion systems and innovative propulsion concepts. Experimental efforts will be aimed at initiating a data base for the combustion performance and heat transfer of metallized hydrocarbon gel fuels and completing activities for the characterization of the rheology and combustion physics of other promising storable and cryogenic gel propellants with very high energy densities. Efforts will also be directed at the verification of models for internal rocket engine flows, including a shear layer model of low-thrust chemical rocket combustion, a three-dimensional coupled combustion instability model, and a viscous multistage turbine model.

In the lunar/planetary propulsion program in 1991, system-level conceptual studies to identify exploration vehicle/propulsion concepts designed to use planetary derived propellants will be completed. Laboratory experiments will yield an understanding of the safety, handling and gelling physics of liquid oxygen and metalloid mixtures. Efforts will be initiated to establish the ignition, combustion and heat transfer characteristics of oxygen/metalloid monopropellants and carbon monoxide and oxygen bipropellants.

Three-dimensional (3-D) Navier-Stokes codes will be developed and applied to low-thrust chemical rockets as part of the overall effort to understand the fundamental physics of rocket combustion. A 5-kilowatt arcjet facility will be completed and made operational, with plans to complete the initial life tests of a 5-kilowatt arcjet in FY 1991. As part of the continuing effort to improve the performance of ion engines for future space exploration, a 500-hour life test of a 5-10 kilowatt ion engine will be completed. Studies will continue to evaluate the effects of adding nitrogen to xenon in order to decrease cathode erosion, and work will be performed to demonstrate and characterize ion thrusters on alternate inert gases such as krypton and argon. Work will continue on moving to higher power levels (over 200 kilowatts) on MPD thrusters to increase the overall efficiency of the device to approximately 40 percent.

Advanced propulsion concept studies will continue toward the objective of identifying fruitful areas for agency emphasis and the critical experiments necessary to prove their potential. The magnetically confined, microwave-induced plasma experiment at the Massachusetts Institute of Technology will be in full test operation as will tests of electrodeless thrusters.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Materials and structures research and technology	20,525	21,600	16,200	16,000

OBJECTIVES AND STATUS

The objective of this program is to provide technology that will enable the development of future spacecraft, large-area space structures, and advanced space transportation systems with significant improvements in performance, efficiency, durability, and economy. Major technical areas of emphasis focus on fundamental understanding of the processing, properties and behavior of advanced space materials, including long-duration synergistic space environmental effects on materials; development of lightweight space-durable materials; computational methods in chemistry to enable the prediction of physical properties and environmental interactions involving materials under space and reentry conditions; nondestructive measurement science for advanced materials; tribological aspects of materials behavior in the space environment; and the development of a wide variety of metallic, intermetallic, ceramic and carbon-carbon materials for thermal protection systems. Structures technology focuses on the development of erectable and deployable structural concepts; methods for in-space construction, monitoring, and repair of large complex structures; dynamics of flexible structures and vibration suppression; new structural concepts for active cooling of hot structures and cryogenic tanks for advanced Earth-to-orbit rocket propulsion systems, future space transportation vehicles, and orbital transfer vehicles; and efficient analysis and design methodology for advanced space structures, including multidisciplinary analysis and optimization.

In the materials science program, efforts are underway to develop theoretical models and experimentally verify methods for predicting the properties of polymers, to develop new high-toughness/high-temperature polymers, to develop new nondestructive measurement capabilities using acoustic microscopy and fiber optic systems, and to conduct fundamental studies of solid lubricants in the space environment. In the space durable materials program, contamination studies are focusing on the development and verification of analytical codes for correlating in-flight data and ground-based experiments. Atomic oxygen studies include developing new ground-based atomic oxygen simulation facilities, conducting a program to compare and calibrate a wide range of ground-based facilities for simulating atomic oxygen exposure in low Earth orbit, and measuring long-term atomic oxygen exposure effects on various organic materials. In the area of micrometeoroid/debris impact, ground-based experimental studies of hypervelocity impact on metallic and

nonmetallic materials are continuing and, in the area of radiation exposure, a new facility is being developed to provide a combined thermal-cycling/electron-radiation testing capability. In the aerothermal materials program, processing, fabrication and testing of various ceramic materials for thermal protection systems are being carried out.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate reflects a reduction of $5.4 million. This includes $2.1 million in generic hypersonic research as part of the general Congressional reduction and a $1.6 million reduction in computer usage. The $1.6 million was realigned to the aerothermodynamics research and technology program. In addition, $1.7 million was realigned from generic hypersonic research in this program to space flight research and technology to support the special investigations of the Long-Duration Exposure Facility (LDEF) spacecraft and systems.

BASIS OF FY 1991 ESTIMATE

In FY 1991, the materials program will continue to place a strong emphasis on space environmental effects on materials and on developing advanced materials with enhanced space durability. The space durable materials program will focus on the long-term effects of combined space environmental factors on materials behavior and on the underlying mechanisms of environmental degradation. The investigations from the LDEF experiments will provide unique data opportunities from its five and one-half years of exposure in low Earth orbit. New emphasis will be placed on the development of experimental and analytical ground-based simulation capabilities for accelerated testing and on methodology for the certification of materials for long-life space applications. Preparations will continue for scheduled flight experiments on atomic oxygen and Shuttle glow phenomena and on collaborative flight experiment opportunities with the Department of Defense and with the European Space Agency. Computational chemistry will continue to develop capability to predict the properties and behavior of bulk polymers, but will also analyze solid-surface interactions to better understand tribological phenomena and surface catalysis. Nondestructive measurement studies will focus on new capabilities to quantify microstructural parameters and fatigue damage characterization in metals. An area which will begin to receive greater emphasis is tribology in the space environment in coordination with a plan to increase emphasis on space mechanisms.

The aerothermal materials and structures activity will continue development and testing of lightweight cryogenic tank concepts and advanced ceramic thermal protection systems (TPS) with higher temperature capability (approximately 3000 degrees Fahrenheit) and high structural strength. Integral cryogenic tank subscale components will be fabricated and tested to verify design concepts for advanced thermal protection systems and structural integrity. Thermal-mechanical tests of a large scale cryotank will be conducted to verify analysis methods. Complex metallic frame and panel structures will be tested under thermal and mechanical loads to verify analysis methods and evaluate performance at temperatures up to 900 degrees Fahrenheit. Ceramic composite TPS design concepts will focus on advanced fabrication methods for flexible insulation materials. Design and analysis emphasis will be placed on developing life prediction methods for actively cooled structures.

Ceramic-ceramic TPS concepts will be fabricated and verified using arcjet tests to achieve the high heating rate environments for hot structures. Research on new TPS materials will include cooperative programs with U.S. and foreign materials suppliers to evaluate advanced ceramic-ceramic composites under high thermal loading conditions. These activities will be supported by a strong program in analytical and experimental methods to predict and verify aerothermal loads and thermal-mechanical response of TPS. An increasing part of this activity will be extensive testing of hot structures, including cryogenic tankage concepts.

The effort in space structural concepts will place continuing emphasis on automated construction methods required for large orbiting scientific instruments and space platforms, including concepts which could apply to potential changes to the Space Station. The payoff is to minimize astronaut extravehicular activity time and reduce mass and packaging volume by up to 50 percent by enabling advanced design concepts. Research on deployable concepts focused on large area precision structures, such as antennas of the type needed for advanced earth observing instruments will also be developed.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space data and communications research and technology........................	8,387	8,800	8,900	8,900

OBJECTIVES AND STATUS

This program is directed toward developing technology to control, process, store, manipulate, and communicate space-derived mission data and enabling new communications concepts.

In the area of advanced data concepts, neural network devices for high reliability space applications have been demonstrated. These neural memory devices may have the potential to replicate the capability of the human mind for pattern recognition and deductive reasoning and will serve as hardware-based natural intelligence for space applications. An erasable neural network-based associative memory system for high reliability space applications was demonstrated. The knowledge-based software engineering environment proof-of-concept demonstration was initiated. A generic software life-cycle model was applied to NASA-managed software projects. These tools are intended to provide software managers with critical tools for evaluation of software development cost and schedule. A reusable software component library in an Ada development laboratory was improved.

Reliable, ultra-high data rate communications links for future NASA missions are predicated upon advances in the communications research and technology base. One watt, high efficiency Ku-Band monolithic microwave integrated circuit (MMIC) amplifiers with a potential use in Space Station EVA terminals were fabricated and tested. Low insertion loss Ka-band MMIC phase shifters were developed for potential use in phased-array antennas for deep-space missions, such as Cassini and Mars Rover. Additionally, a high-speed (> 300 MBits/Sec.) gallium arsenide metal-semiconductor for field effect transistion optical controller chip was fabricated and tested. The device provides 16 parallel outputs for a single serial optical input and has applications in phased array antennas and high-speed computer interconnects. High-temperature superconducting films were fabricated which had superior radio frequency characteristics compared to cryogenically cooled metallic films for millimeter wavelengths. This achievement will enable novel microwave device applications. Long lifetime space-qualifiable lasers are critical for practical space optical communications. A Q-switched, diode-pumped niodium hirium iron garnet laser with pulse rates up

to 50 kilohertz was demonstrated. Advanced high-performance spaceborne transmitter and receiver technology will require semiconductor lasers in both single unit and monolithic array configurations. Injection locked high-power aluminum gallium arsenide diode laser phase-locked arrays have demonstrated 250 megawatts (mW) peak power in a nearly diffraction limited single lobe at 50 millions of bits per second (Mbps). A design study for a Cassini optical communications experiment was conducted and breadboarding of a small optical communications package for Cassini (SCOPE) was initiated.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This has been increased by $0.1 million, which reflects an increase in computer usage. The funding has been realigned from the information sciences research and technology program.

BASIS OF FY 1991 ESTIMATE

A nonvolatile neural network device with learning ability will be validated in the laboratory. The research on sparse distributed memory will continue with emphasis on text recognition and human speech applications. A generic software life-cycle model will be validated by application to a number of NASA-managed software projects. Automated measurement schemes will be implemented in the advanced development of software management environment. Funding is provided to continue support for the software engineering research center at the University of Houston at Clear Lake for continued research in Ada software development, integration, and validation for embedded and distributed systems.

In FY 1991, efforts will continue to increase the efficiency and output power of monolithic microwave integrated circuits (MMIC) operating above Ku-band for satellite and deep-space communications. A high-efficiency Ka-band MMIC amplifier will be completed. Prototype thin-film high-temperature superconducting devices, such as phase shifters and superconducting/normal/superconducting junctions, will be developed. Electron beam technology continues to offer the lowest risk for advanced high data rate deep-space communications. A high-efficiency 32 gigahertz traveling wave tube for planetary missions will be laboratory tested. In the near-Earth laser communications applications area, a performance evaluation of 100-mW quantum well lasers will be completed and an ultra-sensitive 220 Mbps receiver will be evaluated. Breadboarding of the small Cassini optical package experiment (SCOPE) will be completed. This effort will develop the technology required for laser sources for use in free-space optical communications and validate the feasibility of such lasers and other optical communications components.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Information sciences research and technology	7,158	7,500	7,400	15,100

OBJECTIVES AND STATUS

The objective of this program is to provide new concepts, techniques, system algorithms and architectures, hardware devices and components, and software in order to enable viable and productive space information systems.

In the computer sciences area, the Distributed Access View Integrated Data Base (DAVID) system software was installed in numerous astrophysics data systems to provide scientific users a transparent access to space data stored in dissimilar data bases. The new Center of Excellence in Space Data and Information Sciences (CESDIS), established at Goddard Space Flight Center in conjunction with the University of Maryland, initiated research tasks in four major themes with universities across the country. Improvements were made on the prototype intelligent data management system using natural language, expert systems graphics, and a knowledge-based data management controller. At the Center for Aeronautics and Space Information Sciences at Stanford University, studies of importance to NASA have continued to result in doctoral theses in areas such as artificial neural networks. In the concurrent processing research area, research was conducted on the application of sorting as a data routing utility on massively parallel computer architectures.

In the sensing area, the goal of high spatial imaging with simultaneous sharp energy resolution for x-ray and gamma-ray imaging spectrometers and cosmic-ray drift detectors has been advanced by the technique of employing a silicon drift detector to achieve better than 100-electron-volt energy resolution over the soft x-ray spectrum to 10,000-electron volts in energy. These concepts have potential application to the Advanced X-ray Astrophysics Facility and other future missions. A semiconductor diode laser fabricated from gallium antimonide with indium and arsenic in various layers has successfully operated at the eye-safe region of 2.1 micrometers in wavelength at 77 degrees Kelvin.

In photonics research, an advanced pattern recognition system and algorithm was demonstrated. In addition, a liquid-crystal television spatial light modulator for image subtraction, edge enhancement and associative memory applications was demonstrated for application to robotic image identification and recognition. Key spectrum analyzer performance parameters such as resolution, dynamic range, and

tonal cross-talk will be evaluated. Spatial light modulators are the key component in the utilization of the concepts of optical signal processing for applications such as robotic vision and image identification. Real-time holographic writing techniques adaptable to a variety of spatial light modulators will be researched.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This program reflects a decrease of $0.1 million in computer usage which has been realigned to space data and communications research and technology.

BASIS OF FY 1991 ESTIMATE

In computer sciences, research will be conducted under four major themes: information management, concurrent processing, software engineering, and artificial intelligence. The Center for Aeronautics and Space Information Systems (CASIS) at Stanford University will conduct research in neural networks and cellular automation, man-machine systems, high-speed network and telecommunications, and signal processing. The recently established Center for Excellence in Space Data and Information Sciences (CESDIS) at Goddard Space Flight Center will participate in cooperative university and industrial research on NASA long-term space and Earth sciences data and computational problems.

Artificial intelligence techniques for information extraction and autonomous decision making, utilizing high-dimensional multispectral and multisensor image and nonimage data, will be developed and demonstrated. Fundamental research continues in automated technology for ingest, identification, categorization, intelligent data base management processes, such as intelligent query formulation and search strategies based on expert knowledge. Research on concurrent processing algorithms for space research and data analysis will continue, and the software for generic "C" programming language for vector and parallel processors will be prototyped for evaluation.

A general software engineering process simulation (SEPS) model assessing the effect of changes in technology, software engineering development environment, and management policy on various software development projects will be developed.

Several technologies will be developed for high-energy astrophysical research, including a detector with maximum energy range and simultaneous energy resolution. Validation tests will be conducted on an x-ray cooled calorimeter spectrometer with 10-kilo electron volts (keV) sensitivity for x-rays from 0.1 to 10 kilo electron volts (keV), and a room temperature x-ray and gamma-ray spectrometer employing detectors and arrays made from mercuric iodide appears promising. The 2.1-micrometer wavelength region is technologically interesting because detectors exist that can enable better measurements of coherent backscattered radiation. Since this region is also of scientific interest to Earth observations, research will continue on a laser system configuration for remote sensing in this eye-safe wavelength region. Molecular beam epitaxy (MBE) systems will be used for developing the mute quantum-well devices required to make the lasers and detectors in this area.

The area of high-temperature superconductivity (HTS) has broad applications across the spectrum of NASA uses. Thin films are exceedingly important since these are employed in a vast number of detector applications, such as the sensing of electromagnetic radiation, magnetic fields, and use in superconducting cavities for ultra-stable frequency applications in space clocks. Research will continue on the various high-temperature superconducting materials for thin-film devices for space application. Research in bulk materials will also be pursued since their use in magnetic bearings is very important.

HTS magnetic bearings have the potential to increase the efficiency and longevity of mechanical cryocoolers. Advanced low vibration, long lifetime, high-efficiency Stirling coolers will continue to be developed for Earth Observing System (EOS) platforms.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Controls and guidance research and technology............................	5,495	5,600	5,432	4,700

OBJECTIVES AND STATUS

The objectives of this program are: (1) to develop and validate advanced controls algorithms for future complex spacecraft, e.g., large flexible antennas, complex optical light path telescopes and interferometers, multi-instrument Earth observing platforms and Space Stations; (2) to develop computational control tools for spacecraft control system design, analysis, and simulation, where modeling several hundred to thousands of states is required for an accurate description; (3) to produce the technology for advanced sensors and actuators; (4) to provide the basis for onboard guidance, navigation, and control techniques for future space transportation systems; and (5) to define and develop methodologies for the design and validation of highly reliable advanced flight-crucial controllers.

During the past year a large optical sensor and magnetic actuators were successfully integrated into the large flexible vertical beam/antenna test facility at Marshall Space Flight Center. Large disturbance algorithms were successfully tested with the data entered into a data base. The computational controls plan has matured and a user requirements document prepared that supports the range of potential new agency missions, requiring fast efficient analysis and simulation. The fiber-optic gyroscope successfully demonstrated closed-loop navigational grade performance with the eight-component optical chip.

In space transportation technology, precision guidance and navigation concepts and algorithms for adaptive control were developed for passage through planetary atmospheres from space to a safe touchdown area. This research is resulting in improved understanding of aerodynamically assisted orbit transfer aerobraking and aerocapture vehicles. To demonstrate increased fault tolerance and reliability, an engineering breadboard model of an advanced information processing system is now undergoing laboratory testing.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This program has been reduced by $0.2 million. This is the result of a decrease of $0.4 million in generic hypersonic research as part of the general Congressional reduction offset by a realignment of $0.2 million from space flight research and technology to cover increased computer usage.

BASIS OF FY 1991 ESTIMATE

Spacecraft controls algorithms testing and comparisons supporting potential Shuttle flight experiments will be carried out using ground-based capability. Integrated theoretical controls work and supporting sensor technology in the field of precision structures will be advanced. The computational controls plan will be matured, and work will continue to upgrade the analytical tools and capability for analysis of future complex space systems. The successful closed-loop tested fiber-optic gyroscope will be carried forward under a joint Jet Propulsion Laboratory/Charles Stark Draper Laboratory program developing a high fidelity engineering brassboard model. Guidance, navigation, and controls technology will be developed for space transportation vehicles with space station as a transportation node. Emphasis on exploration issues will be placed on the development of algorithms for onboard real-time application and the development of advanced information processing architectures that are highly reliable and fault tolerant. Emphasis will continue to be placed on understanding the optimal balance between hardware and software for operational avionics subsystems to greatly reduce support cost for new generation vehicles, such as the assured crew return vehicle.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology....	4,340	4,600	4,600	3,900

OBJECTIVES AND STATUS

The objectives of this program are to provide a technology base for intelligent operator interfaces, especially with autonomous systems, and to develop a new generation of high-performance space suits, gloves, end effectors and tools to meet the needs of future space activities and missions. These objectives include: development of guidelines for man-machine interfaces in spacecraft and work stations and computer-generated models of human performance capabilities and limitations in weightless or partial gravity environments. The areas of human factors research emphasized are crew-station design and extravehicular activity (EVA).

Crew-station research focuses on: (1) development of human-computer interface technology and graphical presentations, including effective multidimensional visual and aural displays and applications of artificial intelligence to such displays; (2) development of a technology base for autonomous vision and other perceptual systems, virtual work station technology, and computational vision systems for space operations and maintenance; and (3) development of data bases related to human strength and motion and body positions in zero or partial gravity environments. Test and evaluation are emphasized in all three areas.

Extravehicular activity (EVA) research builds on progress in the design, testing, and operational evaluation of EVA suits and subsystems, including gloves, end effectors, and tools needed in EVA.

Research in crew-station operations in FY 1990 has includes updating the finger, hand, and head tracking capabilities of the virtual interactive environment workstation technology and completion of analyses and experiments which allowed an automatic capturing of human visual attention and display. A new method was tested and results published about an electronic display for astronauts' procedures. The data base on human strength, motion and human performance effectiveness was updated.

In the EVA research program, tests of a highly dexterous, multiple degree-of-freedom mechanical end effector in zero-gravity were completed. Tests were completed and demonstration performed on an advanced high-pressure EVA glove concept. An information management system for the EVA-suited astronaut was integrated and included laser-driven visual displays and automatic voice recognition.

Electro-myographic recordings of astronauts' strength and physical workload (heart rate) data was integrated with other quantitative measures of locomotion in microgravity conditions.

BASIS OF FY 1991 BUDGET ESTIMATE

Specific emphasis in crew station design research will be placed on completion of the display techniques and human performance data collection started in prior fiscal years. Research in computational vision system applications for Space Station Freedom and exploration missions will focus on guidelines for the use of the data and methods. Both multidimensional visual and aural displays will be tested in operational settings to verify the adequacy of the concepts. Use of "smart" embedded capabilities will be incorporated in the multidimensional displays.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space flight research and technology.....	18,686	19,400	20,361	15,500

OBJECTIVES AND STATUS

The purpose of this program is to flight test enabling and enhancing technologies which require the actual space environment for validation. Flight data obtained from in-space research and experimentation will be used to validate and verify analytical models, prediction techniques, and ground test methods and facilities. This program encompasses the identification and definition of future in-space flight experiments; the continued design, fabrication, and flight certification of several experiments in preparation for space validation that were initiated prior to FY 1990; and the development of unique, special purpose experiment hardware systems to facilitate technology validation in the space environment.

The space flight experiments being conducted within this program include the cryogenic fluid management flight experiments, Long-Duration Exposure Facility (LDEF) retrieval, light detection and ranging In-Space Technology Experiment (LITE), and the identification and definition of space flight experiments which will provide solutions to future critical space technology problems.

Several cryogenic concepts are being studied to better understand the processes of storage, acquisition, and transfer of cryogenic fluids in the near zero-gravity space environment. Development of specific hardware unique to the success of the experiments (such as flowmeters and fail-safe valves) will continue. Retrieval of the LDEF will be completed and the experiments distributed to the principal investigators for analysis of the flight results. LITE will develop and validate the capability of light detection and ranging (LIDAR) systems as an in-space research tool for measuring aerosols and better understanding the Earth's atmospheric phenomena. The critical design review for LITE has been completed and component fabrication initiated. Two Announcements of Opportunity (AO) will be released in FY 1990. The November 1989 AO will continue the project definition of space flight experiments which have completed feasibility studies within industry or university research programs or through the NASA In-Space Technology Experiments program. The second AO will initiate a new series of flight experiment studies to provide solutions to the critical technology issues identified at the IN-STEP 88 Workshop.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This program has been increased by $1.0 million. This reflects a realignment of $1.7 million from the generic hypersonic in the materials and structures research and technology program for support of special investigations of the LDEF spacecraft and systems. This has been offset by a reduction of $0.7 million in computer usage, $0.2 million of which was realigned to controls and guidance, and $0.5 million was realigned to aerothermodynamics research and technology.

BASIS OF FY 1991 ESTIMATE

Cryogenic experiment concept studies will be continued, and prototypes of the liquid hydrogen and gaseous flow meters and the cryogenic relief valves will be completed. Ground testing of the prototype concepts will provide assurance that these concepts are viable for continued spacecraft development. Data analysis of the flight results of the LDEF will be conducted. Fabrication of the remaining components for LITE will be completed and tested and assembly of the components will be initiated in preparation for a launch readiness date of 1993. A group of space technology experiment definition studies will be initiated to provide solutions for critical technology problems/needs identified in the above-referenced workshop.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Systems analysis........................	6,944	6,900	6,025	6,200

OBJECTIVES AND STATUS

The objectives of this program are to identify technology requirements for key future mission concepts and technology opportunities for enabling new and improved future mission concepts, to integrate these into a comprehensive set of technology planning options, and to generate candidate plans to develop these technologies in a timely manner. Close coordination with the Office of Space Flight, Office of Space Science and Applications, and other users is maintained to ensure proper understanding of missions and to enable better prioritization of high-leverage technologies. This analysis program is directed at the systems areas of space transportation, spacecraft, and large space systems and at emerging, new, mission concepts and mission-enabling technologies.

Analysis of spacecraft systems is concentrated in five science and applications areas: solar system exploration, astrophysics, space physics, Earth science, and communications. Work is focused on defining the critical technologies associated with exploration and global change research, and on defining technologies for future astrophysics missions beyond the Great Observatories.

Analysis of the space transportation systems are focused on evolutionary Earth-to-orbit (ETO) vehicles and advanced space transfer systems. The ETO studies include the identification of high priority technologies which will increase reliability and reduce operations cost for the current Shuttle system developments for future unmanned launch vehicles, and second generation manned vehicles. Vehicle systems analysis tools will be advanced to incorporate integral aerothermal structural analysis and life-cycle costing capabilities.

Analysis of large space systems is focused on providing definition of technology needs relating to the Space Station Freedom in two specific aspects: (1) technologies that may benefit Space Station Freedom operations and evolution, and (2) the utilization of Space Station Freedom facilities for engineering research and technology development experiments.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This program has been reduced by a total of $0.9 million, which includes a reduction of $0.3 million in generic hypersonic research as part of the general Congressional reduction and a reduction of $0.6 million in computer usage, which was realigned to aerothermodynamics research and technology.

BASIS OF FY 1991 ESTIMATE

Many of the long-range efforts currently underway will be continued. These efforts will have substantial impact on the definition of future focused technology program elements, as well as on identifying thrusts for the research and technology base and the flight experiments programs. The spacecraft systems analysis effort will emphasize two areas: (1) continuing the definition of critical and key technologies for future Earth science missions, and (2) identifying the high priority technologies to support future space-based astrophysics missions beyond the Great Observatories, including lunar based astrophysics facilities. Cooperative studies in solar system exploration and space physics will identify technology requirements for key potential future missions.

Effort on the analysis of transportation systems will continue the definition of key areas for lower cost transportation technologies. Aerobrake and engine concepts will be evaluated for both lunar and Mars options, including combined chemical and electric propulsion systems.

In large space systems, a data base on technology needs for Space Station Freedom operations and evolution will be developed by means of a workshop. The needs will be compiled using the various evolutionary scenarios that space station personnel are developing based on the future role of Space Station Freedom in NASA's long-term goals. In addition, the availability of advanced technology to meet long-term need dates will be evaluated. In the area of Space Station Freedom utilization, the experiment planning and the requirements definition will continue as more data on planned experiments become available and station design proceeds.

Efforts will continue to address studies and analyses of opportunity-oriented technologies and their impact on enabling new mission/system capabilities. These studies will explore the potential applications of emerging, high-leverage technologies such as superconductivity, antimatter, and high-level machine learning to the formulation of new or improved system concepts.

BASIS OF FY 1991 FUNDING REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
University space research................	16,210	17,100	17,100	17,700

OBJECTIVES AND STATUS

The objective of this program is to enhance and broaden the capabilities of the nation's engineering community to participate more effectively in the U.S. civil space program. It is an integral part of the strategy to rebuild the space research and technology base. The program responds to the decline in the availability of qualified space engineers by making a long-term commitment to universities aspiring to play a strong engineering role in the civil space program. The program utilizes technical advisors at NASA centers to foster collaborative arrangements, exchange of personnel, and the sharing of facilities between NASA and the universities. The program elements include the university space engineering research program that supports interdisciplinary research centers; the university investigators research program, providing grants to individuals with outstanding credentials; and the university advanced space design program, which funds advanced systems study courses at the senior and graduate levels.

The university space engineering research program is designed to advance the traditional engineering disciplines applicable to space and bring together the knowledge, methodologies, and engineering tools needed to advance future space systems. The research centers promote the kind of multidisciplinary teamwork that systems technological problems demand and bring individuals from a wide range of engineering and scientific fields into a single research structure. These partnerships provide the universities with a broader charter for independent research and enable new mission concepts and ideas that might alter NASA's own visions of the civil space program. In FY 1988, nine universities were selected for their exceptional approaches to provide creative concepts and long-term research under the university space engineering research program. The emphasis will be applied to maintaining the growth of the incumbent university centers to the planned full funding level.

The objective of the university investigators research program is to sponsor individuals doing research on highly innovative space technology concepts directed toward far-term mission use. The grants will be awarded to persons whose past performance has demonstrated the ability to generate and validate innovative concepts.

The <u>university advanced design program</u> objectives are to foster engineering design education in the universities and to supplement NASA's in-house efforts in advanced planning for space systems design. Expanding to a total of 28 universities cooperating with eight NASA installations in 1989, the advanced design program continues to mature and strengthen. The study topics include potential missions which could be undertaken during a 20-30 year period, beginning with the space station initial operating configuration scheduled for the mid-1990's. The university advanced design program has been an effective mechanism for integrating the educational objectives of the university community with the advanced engineering design interest of NASA.

BASIS OF FY 1991 ESTIMATE

Funding will continue to support the nine incumbent centers of the university space engineering research program. Support will continue for eminent researchers selected for participation in the space university investigators research program in FY 1989 and FY 1990, and additional three-year grantees will be added.

BASIS OF FY 1991 FUNDING REQUIREMENTS

CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) PROGRAM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Automation and robotics	25,650	25,900	22,920	25,000
Propulsion	35,521	37,400	22,579	31,400
Vehicle	13,300	36,000	36,000	70,000
Information technology	15,339	15,600	15,002	13,700
Large structures and control	20,450	18,900	16,609	19,800
Power	11,540	10,700	10,700	11,100
Total	121,800	144,500	123,810	171,000

OBJECTIVES AND STATUS

The CSTI program, begun in FY 1988, was the first step in revitalizing national civil space capabilities for future Earth orbit missions. The CSTI is developing technologies to enable efficient, reliable access to Earth orbit, enhance operations in Earth orbit, and increase the effectiveness of science missions from Earth orbit. The vehicle and power elements, within this program, will support the Human Exploration Initiative.

The objective of the automation and robotics program is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs. The automation and robotics element consists of a sequence of evolutionary validation tests using testbeds, mockups and Shuttle and spacecraft operations in five core technology elements: sensing and perception, control execution, task planning and reasoning, operator interface, and systems architecture and integration. The telerobot facility at the Jet Propulsion Laboratory will perform tests in which the concept of traded control between a human operator and automatic control system within a task will be verified. First use of an expert system for monitoring Shuttle communications during flight has been demonstrated. In addition, an autonomous system for thermal control will be validated on a thermal control system testbed.

The objective of the propulsion program is to supply new analytical methods and design tools, which apply fundamental physical and chemical processes and computational fluid dynamics techniques to the design of high-performance engines. These techniques and subsystem codes will be validated through ground tests of

advanced devices and subsystems. The ETO program will also provide new approaches and techniques for health monitoring and lifetime prediction for critical components and devices. These advances will enable the design of high-performance, long-life, liquid oxygen advanced engines.

The Aeroassist Flight Experiment (AFE), which is included in the vehicle area, will investigate critical design and environmental technologies applicable to the design of an aeroassisted Space Transfer Vehicle (STV). Application of this technology has the potential for increasing the payload of an STV by a factor of two for transfer missions from the moon and geosynchronous orbit to low Earth orbit. Computational models and design tools are being developed in the research and technology base to support the design of an STV, but ground facilities are inadequate to provide basic data and to validate concepts. Flight experiments are necessary to provide data and validation in the actual conditions associated with aerobraking in order to reduce unnecessary design margins and obtain the system benefits of aeroassisted STV's. Specifically, the AFE will provide critical aerothermodynamic parameters including radiative heating levels, wake flow base heating levels, aerodynamics and control characteristics, and wall catalysis effects. Alternate thermal protection system materials which permit lightweight, flexible drag devices will be evaluated. The preliminary design of the AFE has been accomplished and reviewed. A large-scale structural test article, representing a one-eighth wedge shape of the aerobrake has been fabricated and successfully passed structural dynamic and acoustic tests. A contract was awarded to fabricate the carrier vehicle and to integrate and test the aerobrake experiments. Advanced computational fluid dynamics codes have been developed and validated with available wind tunnel data. The flow-field and aerodynamic coefficients for the AFE have been computed over the mission trajectory. All of the experiments are under development and are on schedule to support the flight date. The critical design review of the vehicle, associated subsystems, aerobrake, and nine experiments will be performed during FY 1990.

The objective of the information technology program is to develop technologies that will enable active and passive detection and imaging of electromagnetic radiation and the development of advanced techniques, processes, and systems for high-speed/high-volume data storage and processing. This research will develop new techniques, materials, devices, components, and hardware systems concepts. The sensor activities are concentrating on systems for the relatively unexplored submillimeter portion of the electromagnetic spectrum. The data activities are concentrating on technologies for a new generation of high-speed general flight processors and high-volume data handling and storage systems. New sensors operating at submillimeter wavelengths have been developed. Through participation in a multi-agency consortium, technology feasibility studies and demonstration of critical components for a read/write optical disk were completed.

The objective of the large structures and control element is to develop integrated structures and control technology to enable the development of large, flexible and high-precision structures to meet long-range requirements for complex multibody platforms, spacecraft, and large scientific instruments. Current

design and testing methodologies will be inadequate to assure on-orbit performance for integrated structure and control systems at the scale and precision being considered. The precision segmented reflector program is developing technologies for advanced orbiting scientific instruments that use large, extremely precise reflectors which must be lightweight and assembled and aligned on orbit. Systems studies have started, and early lightweight panels have been produced.

In the power area, the high-capacity power program objective is to develop the conversion system technology using a nuclear power source to supply high-capacity power over a long period of time; this program will provide power conversion technology options to be used in conjunction with the nuclear power source being developed in the SP-100 program. (Funding for the SP-100 development is included within the Exploration Technology program.) The emphasis is on thermal-to-electric energy conversion, high-capacity heat rejection, and high-capacity power management and distribution subsystems. Technology validation tests have been completed for a free-piston Stirling engine. Advanced radiator concepts have been identified with one-half the mass of previous systems.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The CSTI program has been reduced by a total of $20.7 million. Of the total reduction, a $17.5 million decrease resulted from Congressional action on the FY 1990 budget request. This was spread across a number of elements within the program, including a reduction of $8.5 million in Earth to orbit technology, $1.0 million in telerobotics, $1.0 million in artificial intelligence, and $1.0 million in control of flexible of structures, and deletion of the total effort in booster technology ($6.0 million). In addition, the sequestration resulted in a further reduction of $3.2 million, which included a reduction of $0.7 million in telerobotics, $0.3 million in artificial intelligence, $1.3 million in control of flexible structures, $0.4 million in science sensor technology and $0.5 million in high rate/capacity data. Within the automation and robotics program, $0.7 million has been realigned from artificial intelligence to telerobotics. The propulsion program reflects a reduction of $0.3 million from the Earth to orbit area to support science sensor technology in the information technology program.

BASIS OF FY 1991 ESTIMATE

The automation and robotics estimate is based on a planned sequence of evolutionary ground demonstrations scheduled to run through 1996. Expert system demonstrations include coordinated control of multiple subsystems, using the thermal control system testbed, and control of the Shuttle environmental control systems during launch processing. Robotics demonstrations will include the addition of an automated planner and the introduction of short time delays to simulate remote location operations.

The propulsion element will continue to conduct technology tasks to verify high-pressure ignition, combustion performance and stability, and heat transfer and cooling. Technical requirements for large-scale turbopumps for code-validation will be documented and design of large-scale combustors will continue. Analytical modeling, code development and advanced design methodologies will continue to be developed. The Space Shuttle main engine technology testbed program will continue with emphasis on testing to help map the internal dynamic environments of that engine for use in verification of simulation codes.

For the Aeroassist Flight Experiment program, the aerobrake will be fabricated and assembled. Both thermal and structural analyses of the aerobrake will be completed for the entire trajectory. All the experiments will be in development in preparation for delivery in FY 1992. A delta critical design review is scheduled to review changes resulting from the critical design review in FY 1990. Fabrication will commence upon completion of the delta review. The spacecraft reaction control system will be procured and assembled and the first inertial measurement unit will be delivered.

The information technology activities will continue to be based on development of detectors in the 4- to 10-micron region using molecular beam epitaxy doping techniques, in the 30- to 300-micron region using blocked impurity band phenomena, and in the submillimeter wave region on quantum-well local oscillator and superconducting tunnel junction mixers, and refrigerator technologies will also be investigated. The high rate/capacity data activities will continue using four-processor, very high-speed, integrated circuit multiprocessors and will start development of a brassboard space flight optical disk recorder module. Preliminary design of onboard digital processors and correlators will be started.

The large structures and control program will develop models and evaluate concepts for integrated structures and control systems. Future systems are expected to be large and flexible and possibly require extreme precision in configuration and control. Concepts of integrated pressure and active control will be investigated. Precision segmented lightweight reflectors will be fabricated; active vibration damping concepts will be developed; and precision panel control will be demonstrated on a single panel. A large truss concept will be fabricated to demonstrate structural precision feasibility.

High-capacity power activities will contain a major contracted effort to develop technologies for the 1050°K Stirling space engine. Component developments will be completed and design efforts to include these components in the engine will be started. Critical technology development and advanced radiator concepts will be pursued for both the engine and thermoelectric space power systems. Technology developments on radiation-hardened, high-temperature power management systems will be performed.

BASIS OF FY 1991 FUNDING REQUIREMENTS

EXPLORATION TECHNOLOGY PROGRAM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space transportation	7,490	8,300	3,300	38,000
In-space operations	4,000	4,500	2,000	23,000
Surface operations	16,485	17,100	13,600	62,000
Human support	5,990	6,300	2,500	25,400
Lunar and Mars science	1,085	1,100	500	4,500
Information systems and automation	--	--	--	10,500
Nuclear propulsion	--	--	--	11,000
Innovative technologies and systems analysis	--	--	--	5,000
Mission studies	4,950	10,000	5,000	--
Total	40,000	47,300	26,900	179,400

OBJECTIVES AND STATUS

The exploration technology program, major segments of which were begun in FY 1989 under the Pathfinder program, is a program through which NASA will develop a broad set of technologies to enable decisions on and development of future space exploration missions. The exploration technology program is a focused technology program that will strengthen the technological foundation of the civil space program and the nation's ability to go forward with future human and robotic solar system exploration missions. This program is organized into eight technology areas: space transportation, in-space operations, surface operations, human support, lunar and Mars science, information systems and automation, nuclear propulsion, and innovative technologies and systems analysis.

The technologies included in the space transportation program are related to timely and cost-effective transportation to and from the Moon and Mars, for both piloted and robotic exploration missions. The technologies included in the in-space operations program area will address critical technologies for in-space assembly and construction and the repair of massive and complex systems in low Earth orbit and at lunar and Martian orbits. The surface operations program area will develop technologies for advanced planetary operations, such as space nuclear power and in-situ resource utilization. The human support program area will address the technology for improving astronaut productivity, maintenance, and health, with minimal or no dependence on resupply of expendables for life support. The technologies included in

the lunar and Mars science program area are related to the gathering of scientific knowledge at mission sites on the Moon and Mars. The information systems and automation program area will develop technologies related to exploration communications, automation, and advanced data processing for piloted and robotic mission applications. The technology developed in the nuclear propulsion program area will address multiple approaches to applying space nuclear power systems to the improvement of mission performance for human missions to Mars.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The Pathfinder (exploration technology) was reduced by a total of $20.4 million as a result of Congressional action on the FY 1990 budget request. This has necessitated reductions in all areas of this program, including $5.0 million in space transportation, $2.5 million in in-space operations, $3.5 million in surface operations, $3.8 million in human support, and $0.6 million in lunar and Mars science, and $5.0 million in mission studies.

BASIS OF FY 1991 ESTIMATE

In the area of space transportation technology, research will continue in cryogenic hydrogen-oxygen engines for space transfer vehicles and for ascent/decent propulsion, including a breadboard and technology for high throttle-ability, long life with multiple firings, integrated engine diagnostics and controls, and design for engine space-basing and servicing; aerobraking for interplanetary mission applications, including computational fluid dynamic aerothermodynamic modeling for both the Earth and Mars atmospheric chemistries; thermal protection systems, such as high-temperature ablative materials; guidance, navigation, and control, including onboard optical navigation for planetary approach and autonomous onboard adaptive guidance to compensate for unanticipated variations in planetary atmospheric densities, and high-energy aerobrake configurations definition for both the Earth and Mars and for robotic and piloted mission applications; in autonomous vehicle maneuvering (both autonomous rendezvous and docking and autonomous landing technologies), including range and range rate active sensors with extended dynamic ranges and onboard guidance, navigation, and control to enable autonomous operations without ground-based human control, and both active and passive landing hazard sensor systems, and low-mass hazard-tolerant landing mechanisms.

In the area of in-space operations technology, research will continue in in-space assembly and construction, including structure component bonding and welding, and techniques for handling large, massive systems elements; cryogenic fluid systems technologies, including microgravity cryogenic fluid analytic modeling, instrumentation to measure cryogen fluid parameters in zero gravity, development of a ground-based testbed for model validation, and definition of flight experimentation requirements for exploration cryogenic fluid systems, Research will be started in the area of vehicle servicing and processing, including automated vehicle systems inspection (including nondestructive inspection and nondestructive evaluation), telerobotic vehicle systems servicing, and vehicle systems automated checkout and test capabilities.

In the area of surface operations technology, research will continue in space nuclear power under the tri-agency (DOD, DOE, and NASA) SP-100 program. This cooperatively funded program is focusing on refractory metal reactors, solid-state thermoelectric conversion, and thermal management technologies such as heat pipes. (Advanced power conversion technologies to be used with the SP-100 reactor are being developed under the CSTI power program.) In planetary rover technologies, research is being conducted to address surface mobility (both wheeled and legged), systems autonomy (including both ground control process automation and onboard software systems), onboard computation and guidance, including semiautonomous navigation and research in mobility robotics. In surface solar power systems, the research focuses on high-performance regenerative fuel cells.

Research will be started in in-situ planetary resource utilization (with a focus on the extraction of oxygen from lunar regolith) and in surface construction and habitats technology (including both the deployment of prefabricated habitat components and in local construction techniques and tools).

In the area of humans support technology, research will continue in regenerative life support systems technology, including air revitalization, water reclamation, environmental monitoring and control, and bioregenerative life support; extravehicular activity suits, including highly-dexterous, high-pressure gloves, suits end effectors and tools, and portable life support systems, including thermal management systems, and carbon dioxide removal; exploration human factors, including human-automation-robotic systems, artificial environment human-machine interfaces, and development of basic human performance models for exploration missions. Research will be started in radiation protection technology, including the development of radiation transport computer models and radiation protection shielding materials and structures.

In the area of lunar and Mars science technology, research will be continued in the area of sample acquisition, analysis, and preservation, including compact multispectral sensor applications for in-situ sample analysis. Research will be started in planetary probes and penetrators for potential application in a Mars network mission, including power supplies, materials and structures, aerodynamic decelerators, and deep penetration and impact-tolerant probe configurations.

In the area of information systems and automation technology, research will be started in high-rate lunar and Mars communications technology, including an initial Ka-Band frequency communications capability and a subsequent optical frequency communications capability; in exploration automation and robotics, including commonly required automation and robotics technologies and/or subsystems such as advanced artificial intelligence-based system executives, vision subsystems, and generalized surface robotic manipulators; and in planetary photonics, including selected very high leverage photonics-based subsystems for exploration applications such as multispectral image processing and high-speed hazard detection processing.

In the area of nuclear propulsion technology, research will be started in nuclear thermal rocket propulsion technologies, including both solid core and gaseous core nuclear system concepts, capable of long-life and multiple starts, for future piloted mission for Mars applications, and in nuclear electric propulsion technologies, including both nuclear reactor systems technologies, advanced low-mass radiator and power management systems, and in high-power long-life electric thrusters for piloted missions for Mars applications.

Definition and management of a major, focused technology development program, such as the Exploration Technology Program, requires the continual re-evaluation of ongoing work, the integration of diverse activities throughout the program, and the incorporation of new technology approaches into the program. NASA intends to solicit new, innovative technologies with the potential for significantly reducing the cost and risk of expanded manned explorations. Promising technologies will receive "seed" funding to determine proof of concept. After feasibility has been established, the selected technolgies will be developed within the other elements of the Exploration Technology Program. Also, the efforts under this program will conduct independent technology analyses and assessments to determine optimum performance technology approaches, and will develop integrated techniques and tools for technology program management and integration.

BASIS OF FY 1991 FUNDING REQUIREMENT

IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
In-space experiments....................	--	16,200	10,200	19,800

OBJECTIVES AND STATUS

The purpose of the In-Space Technology Experiments Program (IN-STEP) is to develop key flight experiments that will provide validated, advanced space technologies to facilitate major improvements in the effectiveness and efficiency of future space systems. Previous efforts in the research and technology base have identified advanced, highly innovative technology concepts that require testing or validation in the actual space environment in order to reduce the risk to potential applications and to increase the rate of transfer of advanced technologies into future space missions. Examples of these technologies include behavior of fluids in the microgravity environment, which is essential for the design of advanced thermal management systems; effect of the space environment on spacecraft; variable gravity effects on heat transfer; effect of contaminates on space systems; and in-space construction techniques (welding).

IN-STEP will coalesce many unique space technology concepts into defined flight experiments and will provide for the development of the flight hardware. This program will concentrate on experiments performed primarily on the Shuttle mid-deck, "getaway special" cans, or combined on cross-bay structures such as hitchhiker. Many will serve as precursors to experiments that will take advantage of the Space Station Freedom facilities that will be available later in the decade. The two major elements of this program are the NASA in-space experiments and industry/university experiments.

Included in these advanced technology experiments are several concepts generated at the NASA research and development centers such as the Return Flux Contamination Experiment (REFLEX), the Thermal Energy Storage Materials Testing (TEST) experiment, the Debris Collision Warning Sensor (DCWS) experiment, and several innovative concepts currently in the definition phase. The REFLEX experiment will identify the types and quantities of contaminates surrounding the spacecraft. The TEST experiment will validate concepts for storage of energy on spacecraft for later use when normal energy sources (such as the Sun) are unavailable. The DCWS experiment will validate a sensor concept which measures and identifies small debris in low Earth orbit that could be detrimental to spacecraft, space structures, and the safety of man. This debris is currently undetectable by ground radars and telescopes or current space sensors. These experiments should complete the design phase during FY 1990 and be in the hardware development phase for space flight experiments.

The industry and university technology experiments program was initiated with a solicitation for flight experiments in 1986 which resulted in the identification of over 200 innovative space technology concepts generated through U.S. industry and university research. Forty-one experiments were selected for definition or development. Thirty-six of the most critical technologies have completed the definition phase for in-space flight experiments. These 36 experiments will compete in an Announcement of Opportunity with other industry and university concepts for continuation into the flight hardware design, fabrication, and testing phase. Five experiments have completed design studies and are initiating the detailed design, fabrication, and ground certification in preparation for flight testing. Typical examples of these five experiments are the Tank Pressure Control (TPC) and the Experimental Investigation of Spacecraft Glow (EISG) experiments. The TPC experiment will validate predicted mixing and thermal stratification characteristics of fluids in a zero-gravity environment influenced by jet-induced flow. Data collected during flight may significantly reduce cost and complexity of fluid tanks in future spacecraft. The glow experiment will study the causes and effects of ram-induced radiation observed about certain materials when subjected to the space environment. A better understanding of the glow phenomena may reduce erosion of space structures and may provide an effective means of identifying/characterizing future spacecraft.

CHANGES FROM FY 1990 BUDGET ESTIMATE

This program was reduced by $6.0 million as a result of Congressional action on the FY 1990 budget request.

BASIS OF FY 1991 ESTIMATE

Funding will provide for the continued development of the selected space technology experiments for flight validation on the Space Shuttle and/or Expendable Launch Vehicles in FY 1991 through FY 1993. Hardware design and fabrication will be initiated on the REFLEX, DCWS, TEST, and the five flight experiments currently under development in the industry and university program. Hardware design and development for key flight experiments selected from the FY 1990 Announcement of Opportunity will be initiated in preparation for in-space technology experiments on launch vehicles during FY 1994 through FY 1996.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

EXPLORATION MISSION STUDIES

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
	(Thousands of Dollars)				
Exploration mission studies.............	(14,950)	(20,000)	(15,000)	37,000	RD 15-1

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center.....................	(5,273)	(12,280)	(7,280)	28,000
Marshall Space Center....................	(1,720)	(3,000)	(3,000)	4,000
Goddard Space Center.....................	(149)	(--)	(--)	--
Jet Propulsion Laboratory................	(3,221)	(400)	(400)	--
Ames Research Center.....................	(725)	(100)	(100)	--
Langley Research Center..................	(887)	(--)	(--)	--
Lewis Research Center....................	(1,215)	(220)	(220)	--
Headquarters.............................	(1,760)	(4,000)	(4,000)	5,000
Total....................................	(14,950)	(20,000)	(15,000)	37,000

OBJECTIVES AND JUSTIFICATION

On July 20, 1989, President Bush set a new course for the Nation stating: "I'm proposing a long-range continuing commitment: first, for the coming decade, for the 1990's, Space Station Freedom, our critical next step in all our space endeavors. And next, for the new century, back to the Moon, back to the future, and this time, back to stay. And then a journey into tomorrow, a journey to another planet, a manned mission to Mars. Each mission should and will lay the groundwork for the next." The President has set the course for the U.S. to "expand human presence and activity beyond low Earth orbit into the solar system."

During FY 1988 and FY 1989, NASA's efforts were focused on studying alternative exploration pathways and strategies that would fulfill the objective of expanding human presence and activity beyond Earth orbit. Pathways/strategy combinations were characterized as case studies. Case studies that were analyzed include: Mars expedition, Mars evolution, Lunar evolution, and Lunar evolution to early Mars outpost. These cases were refined through mission and systems engineering studies to define a full set of concepts and requirements for each case. Requirements defined included prerequisite program requirements in the areas of life science research, Earth-to-orbit transportation systems, Space Station Freedom evolution, advanced technology development, and robotic scientific missions. These prerequisite programs lay the foundation for later manned exploration missions. Additional requirements were defined in areas such as planetary surface activities, scientific research, in-orbit vehicle assembly facilities, and space transfer vehicle design.

After July 20, 1989, the focus of NASA's exploration studies was revised to respond to the President's initiative. To this end, NASA recently completed a 90-day study of human exploration of the Moon and Mars. The final report of this study was delivered to the NASA Administrator to be used as input to the National Space Council's exploration planning efforts.

For FY 1990, exploration studies will continue to focus on strategies for developing the President's initiative. A major activity of FY 1990 will be the review of innovative ideas developed by various agencies, businesses, and organizations throughout the country. These ideas will be reviewed by NASA for their possible application tothe President's initiative. Also in FY 1990, various groups such as the NASA Advisory Council and the National Research Council will perform independent reviews of NASA's exploration planning activities.

CHANGES FROM FY 1990 BUDGET ESTIMATE

FY 1990 funding, which is contained within the Space Research and Technology, Space Science and Applications, and Space Transportation budgets, is reduced in order to accommodate the Congressional general reduction.

BASIS OF FY 1991 ESTIMATE

In FY 1991, a series of mission studies, technology trades and analyses of science opportunities will be initiated. This encompasses mission integration studies in transportation systems, surface systems development and use of in-situ resources, power and propulsion systems, life support requirements and robotics, a contractor mission analysis program and innovative mission concept studies. These studies will provide NASA with mission design options and the effects of alternative scenarios, prerequisite mission requirements and technology requirements on NASA infrastructure and systems for the President's initiative.

FY 1991 is the first year of direct funding for exploration study activities managed by the Office of Aeronautics and Space Technology in a consolidated budget line item. Prior year funding for exploration mission studies is shown parenthetically because it was contained within the Space Research and Technology, Space Science and Applications, and Space Transportation budgets, consistent with the focus of each program office.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SAFETY, RELIABILITY MAINTAINABILITY AND QUALITY ASSURANCE

SAFETY, RELIABILITY AND QUALITY ASSURANCE

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Safety, reliability, maintainability and quality assurance..................	22,400	23,300	22,630	28,000	RD 16-2
Applied technology.....................	--	--	--	5,000	RD 16-2
Total..................................	22,400	23,300	22,630	33,000	

Distribution of Program Amount By Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center.....................	1,534	2,500	1,400	2,150
Kennedy Space Center.....................	437	500	500	600
Goddard Space Flight Center.............	1,315	1,900	1,400	2,400
Jet Propulsion Laboratory...............	3,021	3,500	2,900	3,650
Ames Research Center....................	152	500	100	200
Langley Research Center.................	3,635	3,800	2,100	2,800
Lewis Research Center...................	1,410	2,000	1,000	3,700
Marshall Space Flight Center............	672	1,800	1,000	2,100
Stennis Space Center....................	120	--	150	150
Headquarters............................	10,104	6,800	12,080	15,250
Total..................................	22,400	23,300	22,630	33,000

OBJECTIVES AND JUSTIFICATION

The Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) program continues to actively support NASA agency-wide goals. This is achieved by the implementation of procedures that reduce program risk: safety, reliability, quality assurance, maintainability, systems assessment, and program assurance (including independent assessment and trend analysis activities). Specific program objectives are:

- Develop and implement top-level NASA safety policies, and define program-specific safety requirements.

- Develop an independent mission safety evaluation for each mission, and an independent capability to perform technical assessments to support the SRM&QA decision process.

- Provide technical guidance and support to NASA programs, including Shuttle readiness reviews and launch operations.

- Support a risk management program that provides management visibility into problems and technical risks, and provides analyses and corrective actions.

- Develop a human factors engineering program and promulgate safety tools and techniques.

- Conduct independent quantitative risk assessments, and perform hazard analyses.

- Provide functional management in reliability, maintainability and quality assurance for software assurance, electronic and mechanical parts and assemblies, and standards assurance.

- Develop and evaluate cost-effective quality programs.

- Assure development and maintenance of systems to communicate problems and provide tools which analyze trends and predict and prevent serious problems.

- Review and evaluate NASA and contractor SRM&QA activities to verify conformance with established policies and procedures.

- Continue to improve the automation of the SRM&QA Management Information Centers, while developing procedures and systems to effectively manage SRM&QA data.

- Foster a total quality management philosophy throughout NASA and its contractors and suppliers.

STATUS

Substantial effort is currently being devoted to ensuring that appropriate safety and reliability requirements are integrated into the earliest phases of future manned and unmanned space flight systems, as well as the aeronautics programs. Support on a NASA-wide/industry basis continues in the areas of integrated circuit product assurance, materials treatments and processes, microcircuit radiation effects evaluation, and aerospace and system safety related matters.

SRM&QA will initiate a certification program for mechanical parts. Efforts include a subtier supplier control system and a process which will identify the relationship between out-of-tolerance conditions and loss-of-strength, optimize reliability of parts, and reduce risk. Testing of ionizing radiation and investigation of solder fatigue related to long-term space programs is also planned.

Software complexity is being addressed in depth; recent NASA missions have required larger, more complex critical software than those of the past. A comprehensive software management and assurance program which addresses NASA's critical software intensive systems will be developed. Methods, procedures, and tools to evaluate software assurance within the software process will be continued to keep pace with advanced systems.

Methods and procedures to identify and analyze risk associated with the Space Station Freedom (SSF) program and the increasing launch rate of the National Space Transportation System are currently being addressed. On-orbit metrology and calibration capability for SSF is being developed. Key activities associated with Space Station include the review of design/development issues, e.g.; on-orbit fire safety, structural vibration, fabrication timeliness, on-orbit maintenance and repair, and the use of 120v DC power.

A formal "Lessons Learned" program is planned to assure that all technical and operational lessons and ensuing knowledge will be captured and translated into appropriate documentation.

The Office of Safety, Reliability, Maintainability and Quality Assurance is extensively and aggressively involved across all levels of NASA programs to ensure design safety, operations logistics, and program management. Emphasis continues to be placed on providing leadership to all operational, programmatic, and institutional activities of the agency.

CHANGES FROM FY 1990 BUDGET ESTIMATE

As a result of general Congressional reductions and sequestration there is a total reduction of $0.7 million in FY 1990. This reduction will be accommodated through deferral of planned work in safety and risk management, integrated assurance information, and software quality assurance.

BASIS OF FY 1991 ESTIMATE

The SRM&QA program will continue to provide leadership to all operational, programmatic, and institutional activities of the Agency in areas of its responsibility. The key ingredient of this leadership is the continued integration of top level SRM&QA policies, procedures, and standards into each NASA program area. Preferred techniques for implementing key reliability requirements continue to be developed. These techniques will ensure that the most current and effective methods in reliability engineering will be applied to all NASA programs thus optimizing reliability, reducing risk, and enhancing mission effectiveness. The non-destructive evaluation measurements assurance program will continue to provide state-of-the-art, quantitative, advanced inspection techniques for solid rocket motors, composites, and ceramics. The program will also explore advanced inspection techniques such as microfocus x-ray, fiber optics, acoustic emission, computer tomography, and laser technology. The systems assessment program will continue to provide independent "second look: assessments of major Space Transportation System flight hardware issues. In the Reliability, Maintainability, and Quality Assurance program additional work will be performed in the mechanical parts program and SSF support.

The applied technologies program will be initiated to enhance safety,reliability, and maintenance assurance in areas critical to NASA missions. An aerospace flight battery systems program will provide a strong battery technology reliability and maintenance capability with an independent system of checks and balances. An aerospace flight pyrotechnics systems program will enhance NASA's flight pyrotechnic safety, reliability, quality, and performance. Additional areas of interest are: manufacturing technologies, nonmetallic materials processes and standards, hardware, valves, relays, wire, mechanical connectors, fasteners, and chlorofluorocarbon replacements.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Educational affairs	(12,600)	15,900	16,497	23,300	RD 17-2
Minority university research	(9,700)	14,100	13,744	16,800	RD 17-10
Space grant college and fellowship	(1,275)	5,000	6,797	10,000	RD 17-16
Total	(23,575)	35,000	37,038	50,100	

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RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS | **EDUCATIONAL AFFAIRS**

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Graduate student researchers.............	(5,000)	6,800	6,500	6,900	RD 17-4
Summer faculty fellowships...............	(2,500)	3,800	3,631	3,800	RD 17-5
Innovative research......................	(2,400)	2,500	2,390	2,700	RD 17-6
Space applications.......................	(2,700)	2,800	3,976	2,800	RD 17-7
*Aerospace education services (AESP).....	(2,966)	(2,300)	(2,613)	3,905	RD 17-8
*Innovative student/teacher..............	(1,472)	(1,426)	(1,426)	3,195	RD 17-9
Total..................................	(12,600)	15,900	16,497	23,300	

* FY 1989 and FY 1990 funding is included in the Research and Program Management account.

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Ames Research Center.....................	(683)	1,023	1,023	1,053
Goddard Space Flight Center..............	(675)	952	952	982
Jet Propulsion Laboratory................	(636)	907	907	937
Johnson Space Center.....................	(579)	934	934	964
Kennedy Space Center.....................	(175)	435	435	465
Langley Research Center..................	(773)	1,095	1,095	1,125
Lewis Research Center....................	(604)	928	928	958
Marshall Space Flight Center.............	(685)	930	930	960
Stennis Space Center.....................	(36)	509	509	539
Headquarters.............................	(7,754)	8,187	8,784	15,317
Total..................................	(12,600)	15,900	16,497	23,300

ACADEMIC PROGRAMS

EDUCATIONAL AFFAIRS

OBJECTIVES AND JUSTIFICATION

The Educational Affairs program, as well as the Minority University Research program and the Space Grant College and Fellowship program, to be discussed below, became a new budget line item in FY 1990.

The goal of the NASA Educational Affairs program is to create and maintain strong and mutually productive working relationships with the Nation's university and elementary and secondary education community. To accomplish this goal the Office of External Relations and the Office of Space Science and Applications manage certain unique university programs that are agency-wide in scope and interest but are not within the direct responsibility of NASA program offices. Beginning in FY 1991, we have combined our elementary and secondary educational programs with the university programs for a consolidation of NASA's educational programs.

The specific objectives of the Educational Affairs program are:

- To significantly increase the number of highly trained scientists and engineers in aeronautics, space science, space applications and space technology to meet the continuing needs of the national aerospace effort.

- To facilitate the direct interaction, further the professional knowledge and stimulate the exchange of ideas between university faculty members and NASA scientists and engineers.

- To support innovative research at U.S. institutions of higher learning, research that is in the formative or embryonic stage and that would appear to have significant potential to advance space science and applications programs.

- To provide for the development and use of a core, long-term U.S. national university capability to conduct multiyear, Earth science discipline-oriented applied research and remote sensing.

- To encourage elementary level students to take greater interest in mathematics, science, and technology through the use of advanced instructional technology, development of strong teacher resource centers, curriculum materials designed for the elementary level, and to initiate cooperative relationships with private industry, local school systems, and community organizations.

- To involve the educational community, both students and teachers, in better understanding the knowledge derived from NASA research and development through information dissemination, teacher workshops, and aerospace oriented learning activities.

- To stimulate interest in science and technology through direct involvement of secondary school students in space research by providing opportunities to propose experiments for possible testing in NASA facilities.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The total increase of $597 thousand in FY 1990 is the net result of a $1 million reallocation from the additional funding appropriated for the Space Grant College and Fellowship program and the reallocation of $300 thousand within other educational programs to provide $1.3 million funding for an innovative "classroom of the future", offset by reductions of $250 thousand as part of the general reduction directed by P.L. 101-144 and $153 thousand for sequestration.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Graduate student researchers.............	(5,000)	6,800	6,500	6,900

OBJECTIVES AND STATUS

The Graduate Student Researchers Program, initiated in 1980, provides graduate fellowships nationwide to post-baccalaureate U.S. citizens to conduct thesis research at a NASA Center or to carry out a program of study or research at their home institution. From 1980-1984, approximately 40 new awards were made each year. In 1985, NASA doubled the size of the program to make 80 new awards each year. Awards are made to graduate students for a maximum of three years. On an annual basis, NASA supports approximately 250 graduate students pursuing the masters or doctorate degrees.

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CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $300 thousand reflects implementation of Congressional appropriations action; the reduction will be implemented by reducing the number of available grants.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding will allow for the continuation of the current program including the continuation of the Graduate Student Researchers program at the John C. Stennis Space Center initiated in FY 1990, as well as continuing to increase the number of annual awards available yearly at each NASA center.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Summer faculty fellowships...............	(2,500)	3,800	3,631	3,800

OBJECTIVES AND STATUS

The NASA Summer Faculty Fellowship program has completed 26 years of operation. This program provides highly beneficial opportunities for engineering and science faculty throughout the United States by allowing participation in NASA research. This program has contributed significantly to the improvement of both undergraduate and graduate education, and directly benefited NASA, universities, faculty, students, and the Nation.

The Summer Faculty Fellowship program enables university faculty to spend ten weeks working directly with scientists and engineers at NASA Field Centers on problems of mutual interest. Participants must have a minimum of two years teaching experience and must be citizens of the United States. The program is designed to further the professional knowledge of faculty members, to stimulate an exchange of ideas between participants and NASA, and to enrich the research and teaching activities of the participants' home institutions. This activity is operated cooperatively with the American Society for Engineering Education (ASEE).

Approximately 200-250 university faculty are supported annually for ten weeks. Evaluations conducted by ASEE of the program indicate that approximately 30-40 percent of the participating faculty subsequently receive NASA research grants or contracts.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $169 thousand reflects implementation of Congressional appropriation action; it will be effected by reducing the number of available grants.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding level supports program continuation at current activity levels.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Innovative research......................	(2,400)	2,500	2,390	2,700

OBJECTIVES AND STATUS

Over the past decade, it has become increasingly apparent that a key to the future health and well-being of the space science and applications program lies in having the capacity to explore new ideas or novel technical approaches to research. In response to this need, the Innovative Research program was established within the Office of Space Science and Applications to support research which, while still in its formulative stage, has already demonstrated potential for significant advances for space science and application programs. The program is intended to provide a mechanism for the funding of scientifically sound proposals which might not be funded through normal channels either because of their inter-disciplinary nature or because they are, in some sense, speculative or risky. The long-term goal is to help the new ideas mature to a state of acceptability within particular science discipline resources.

The Innovative Research program was initiated in 1980, with announcements of the availability of funds and NASA's interest in receiving proposals for this type of research having been issued in 1980, 1982, 1985, and 1988. Emphasis in the program has been on the support of innovative research at universities and colleges. The primary criterion for inclusion in the program has been the originality and promise for innovation of the work being proposed. Over the past several years, a number of major technical advances have resulted from research supported by this program, such as the development of new infrared detector technology by the University of California-Berkeley using non-standard scientific approaches.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $110 thousand reflects implementation of Congressional appropriations action; it will be effected by reducing the number of available grants.

BASIS OF FY 1991 ESTIMATE

As a result of the 1989 review cycle, 20 investigations at 20 institutions were selected with levels of support ranging between $60,000 and $200,000 per year. Awards were for one to three-year periods to allow adequate time for the development and demonstration of the validity of new ideas. A few additional awards have been initiated out of program reserve funds, recognizing that innovation cannot be scheduled on a three year announcement schedule. The requested FY 1991 funding will provide for continuation of the current program and allow a few additional awards to be initiated.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space applications......................	(2,700)	2,800	3,976	2,800

OBJECTIVES AND STATUS

The objectives of the Space Applications program are to provide, through university grants, for the development and use of a core U.S. national university capability to conduct multiyear, discipline oriented basic and applied research in space applications; and to establish and maintain multidisciplinary remote sensing techniques and the use of those techniques in furthering the understanding of Earth sciences. This program has been the major impetus for the development of a geographically distributed network of universities which now comprise the prime source of the research and the development of techniques designed to use remote sensing data in the study of global Earth science processes and Earth resources management. In addition, funds will be provided to Wheeling Jesuit College, Wheeling, West Virginia, to establish and equip a computer software facility which will be used to develop software for space science education at the college and other sites throughout the Nation. During FY 1990, NASA plans to work with Wheeling officials to research and develop the concept of a "classroom of the future."

CHANGES FROM FY 1990 BUDGET ESTIMATE

The increase of $1,176 thousand is the net result of providing $1,300 thousand to initiate an innovative "classroom of the future" offset by reductions of $124 thousand as part of Congressional reductions.

BASIS OF FY 1991 ESTIMATE

This program has achieved considerable success in developing a community of researchers knowledgeable in remote sensing science and in contributing toward the overall evolving maturity of spaceborne remote sensing. In FY 1991, the Space Applications program will focus on working with the university community to prepare for the space-based remote sensing of the Earth in the Space Station era. In this time frame the Earth Observing System (EOS) will be a key tool for moving both the fundamental and applied aspects of Earth system science forward. EOS is a complex set of instruments which the university community must become more familiar if we are to continue to maintain this nation's leadership position in Space Applications. In addition, key research thrusts, such as Global Change, must include university researchers as well. University involvement in the space based aspects of this program will provide the training and long-range research core which will be able to exploit data collected on decadal time scales.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Aerospace education services (AESP)......	(2,966)	(2,300)	(2,613)	3,905

OBJECTIVES AND STATUS

The Aerospace Education Services Program (AESP), previously known as Spacemobile, is a vital outreach program. AESP specialists, all former teachers themselves, stimulate millions of students and teachers each year by using aeronautics and space as a catalyst in the teaching of science, mathematics and technology. From September to June each year AESP specialists visit schools throughout the United States, conducting student assemblies and teacher workshops. During the summer, AESP specialists conduct teacher workshops at the NASA field centers and various colleges and universities. This program was transferred from the R&PM appropriation in order to consolidate the Educational Affairs program in FY 1991.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding will allow for continuation of the current program with increases targeted toward adding additional specialists and upgrading instructional models and vans.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Innovative student/teacher...............	(1,472)	(1,426)	(1,426)	3,195

OBJECTIVES AND STATUS

The Innovative Teacher Involvement program is an umbrella term that represents a series of programs targeted at both pre-college teachers and students. The goal is to enhance and improve the teaching of science mathematics and technology at the elementary and secondary level by using aeronautics and space as a theme and motivational factor. Programs included are: NASA Education Workshops for Math and Science Teachers (NEWMAST), NASA Education Workshops for Elementary School Teachers (NEWEST), the Space Science Student Involvement Program (SSIP), Space Exposed Experiment Developed for Students (SEEDS), Teacher Resource Centers, and the Summer High School Apprentice Program (SHARP). This program was transferred from the R&PM appropriation in order to consolidate the Educational Affairs program in FY 1991.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding will allow for continuation of the current program with increases in the level of activity targeted toward underrepresented minority students through the SHARP activity, additional sites for Teacher Resource Centers, and continuation of the SEEDS program.

ACADEMIC PROGRAMS — **MINORITY UNIVERSITY RESEARCH**

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Historically black colleges and universities	(7,700)	8,900	8,544	9,100	RD 17-12
Other minority universities	(--)	2,000	2,000	4,000	RD 17-13
Graduate student researchers program (underrepresented minority focus)	(2,000)	2,200	2,200	2,200	RD 17-14
Undergraduate student researchers program (underrepresented minority focus)	(--)	1,000	1,000	1,500	RD 17-15
Total	(9,700)	14,100	13,744	16,800	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	(422)	1,420	766	786
Kennedy Space Center	(38)	550	466	472
Goddard Space Flight Center	(674)	1,204	830	850
Jet Propulsion Laboratory	(--)	850	--	--
Ames Research Center	(542)	224	253	259
Stennis Space Center	(565)	314	284	292
Langley Research Center	(2,473)	2,368	2,852	2,770
Marshall Space Flight Center	(582)	1,775	616	632
Headquarters	(4,191)	5,077	7,535	10,593
Lewis Research Center	(213)	318	142	146
Total	(9,700)	14,100	13,744	16,800

ACADEMIC PROGRAMS | MINORITY UNIVERSITY RESEARCH

OBJECTIVES AND JUSTIFICATION

The goals of the NASA Minority University Research program are to implement aggressively the initiative for Historically Black Colleges and Universities (HBCUs); develop closer relationships with minority universities other than HBCU's; maintain the Graduate Student Researchers program (Underrepresented Minority Focus); and continue an Undergraduate Researchers program (Underrepresented Minority Focus) established in FY 1990.

NASA's HBCU initiative is mandated by Executive Order 12677 (which replaced EO 12320 of the previous administration) which requires Federal agencies to increase significantly the involvement of HBCUs in Federally sponsored programs. NASA has implemented this initiative primarily through research and training grants.

In FY 1985, Congress instructed NASA, through the Reports of the House Committee on Science and Technology, the House and Senate Appropriations Committees and the Senate Committee on Commerce, Science, and Transportation, to build closer relationships with other universities that educate large numbers of minority students who are underrepresented in science and engineering, while not diminishing the agency's efforts towards the HBCUs. NASA made a commitment to Congress to: (1) establish or expand our research and development (R&D) relationship with a few selected universities; (2) encourage principal investigators to add underrepresented minorities to their research grants; and (3) increase participation of universities with substantial numbers of underrepresented minorities in our Co-op programs, faculty summer assignments, graduate student researchers, post-doctoral fellowships and other programs.

NASA introduced an Undergraduate Researchers program (Underrepresented Minority Focus) in FY 1990 based on the recommendations of NASA principal investigators. The concept also is consonant with the recommendations of the national Task Force on Women, Minorities, and the Handicapped in Science and Technology which urged the establishment of a variety of scholarships, fellowships, hands-on research experience, and other support to capture and develop these groups. It has become increasingly apparent that many promising minority high school graduates with excellent grade point averages and SAT scores enter college, but do not elect science and engineering fields; and many of the minority science and

engineering students who succeed at the undergraduate level and who have the ability to do graduate level research, never consider research as a career option. NASA Principal Investigators report that very few graduate-level minorities are available; however, they can find minorities at the undergraduate level and encourage them to pursue graduate degrees. Thus, the objective of this program is to build a pipeline of undergraduate minority students and ensure increased numbers for graduate studies.

In all of the above programs, NASA's ultimate goals are to encourage strong research focus and alliances between HBCUs, other minority universities, majority research universities, industry, and other Federal R&D agencies; and to help develop the resource pool of future talent that will be needed by this agency, those institutions and the Nation.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $356 thousand from the FY 1990 budget reflects the Congressional general reductions and sequestration.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Historically Black Colleges and Universities	(7,700)	8,900	8,544	9,100

OBJECTIVES AND STATUS

The objectives of the HBCU program are to increase significantly HBCU participation in NASA sponsored programs; increase and strengthen their research infrastructure, curriculas and faculty capabilities; help develop a cadre of minority undergraduate and graduate science and engineering researchers at the HBCUs; and involve private sector institutions in the NASA/HBCU initiatives.

NASA will continue to sponsor, promote and encourage individual and team research and training grant projects and programs which include the participation of undergraduate and graduate students. In addition, NASA will continue supporting the HBCU-Space Science and Engineering Centers for Excellence (SSECE) established in FY 1990, and continue its commitment to upgrade scientific and technical research and development capabilities of a few of the most productive HBCUs. This initiative will expedite the strengthening of the institutions' research infrastructure and curricula, increase the number of minority faculty and students engaged in meritorious scientific research, and help the universities become renowned as major centers of excellence in their chosen areas.

In FY 1989, 23 HBCUs were involved in relationships with NASA; and they were the recipients of 77 research and development and 14 training grant awards. These universities received funds from the basic budget above and as a result of awards directly funded from program and installation budgets.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $356 thousand from the FY 1990 budget estimate reflects the Congressional general reduction and a reduction for sequestration. This will reduce the level of funding for the HBCU-Space Science and Engineering Centers for Excellence.

BASIS OF FY 1991 ESTIMATE

In FY 1991 in addition to continued funding for HBCUs, NASA plans to fund the HBCU-SSECE established in FY 1990. At least a five year commitment is anticipated. A comprehensive annual evaluation of center program efforts will be conducted to determine the effect on constituent users; and the results will be utilized for program modifications for subsequent funding periods or for decisions concerning further expansion.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Other minority universities..............	--	2,000	2,000	4,000

OBJECTIVES AND STATUS

In response to the instructions of various Congressional committees to initiate and expand our relationships with universities with substantial numbers of minority students without diminishing our efforts with HBCUs, NASA will establish and/or expand its relationships with universities with significant populations of minorities who are traditionally underrepresented in science and engineering. It is anticipated that these other universities will be selected on the basis of a combination of factors, such as science and engineering curricula and accreditation, research capabilities, and significant numbers of underrepresented minority students and faculty. These other universities will be encouraged to increase their participation in NASA's research and technology, educational opportunities, and services.

BASIS OF FY 1991 ESTIMATE

FY 1991 funding will provide an increase to research grant efforts for a few selected minority universities other than HBCUs. This effort will expedite the strengthening of their research infrastructure and curricula, to increase their minority faculty and students engaged in meritorious scientific research, and provide an opportunity to become renowned as an institution of excellence in their chosen fields.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Graduate student researchers program..... (Underrepresented minority focus)	(2,000)	2,200	2,200	2,200

OBJECTIVE AND STATUS

The objectives of this program are to enhance the development of underrepresented minority talent in an effective way so as to utilize the potential of this nation's diverse citizenry; and to increase the size of the resource pool of research skills that will be needed to meet aerospace and other technological objectives of the future. Principal investigators who have NASA research grants, and a need for further student involvement, will be encouraged to seek out talented underrepresented minority students and involve them in their NASA research projects. The underrepresented minorities who are the special focus of this program are Blacks, Hispanics, American Indians and Pacific Islanders. They must be enrolled in masters or doctoral programs in engineering, physics, mathematics, computer science, biology, or other disciplines of interest to NASA in aeronautics, space and life sciences.

In FY 1989, the third year of the program, an additional 55 underrepresented minority students were selected to make a total of 117 participants in the program. These included 55 Blacks, 52 Hispanics, 6 American Indians and 4 Pacific Islanders.

BASIS OF FY 1991 ESTIMATE

The funds provided in FY 1991 will be used to continue the current program.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Undergraduate student researchers program (Underrepresented minority focus)	--	1,000	1,000	1,500

OBJECTIVES AND STATUS

This new program, begun in FY 1990, identifies freshman level high potential underrepresented minority students attending majority universities and majoring in science and/or engineering; and will serve as a feeder to the Graduate Student Researchers program (underrepresented Minority Focus). Identified students will receive tuition support; will be monitored, tutored and nurtured; and by their junior year, will become research assistants working with principals investigators at their universities on NASA sponsored research. The primary objective is to encourage talented underrepresented minorities to choose, as a career option, graduate level studies in science and engineering.

BASIS OF FY 1991 ESTIMATE

The funds provided in FY 1991 will allow for a gradual buildup of the program bringing the level of activities to the approximate level of the Graduate Student Researchers program. Since the undergraduate component will serve as a feeder to the graduate component, the proposed budget structure for the undergraduate component represents a natural progression. NASA's goal is to have a continuous flow of minority undergraduate and graduate level students in science and engineering educational tracks.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS

NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIPS

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space grant college and fellowship.......	(1,275)	5,000	6,797	10,000
Distribution of Program Amount by Installation				
Headquarters............................	(1,275)	5,000	6,797	10,000
Total.................................	(1,275)	5,000	6,797	10,000

OBJECTIVES & JUSTIFICATION

As enacted in NASA's FY 1988 Authorization Act (P.L. 100-47), the National Space Grant College and Fellowship program is designed to broaden the base and enhance the capabilities of the university network capable of contributing, through research, education and public service, to the increased utilization of space and its resources.

The objectives of the program are to:

(1) Increase the understanding, assessment, development, and utilization of space resources by promoting a strong educational base, responsive research and training activities, and broad and prompt dissemination of knowledge and techniques;

(2) Utilize the abilities and talents of the universities of the Nation to support and contribute to the exploration and development of the resources and opportunities afforded by the space environment;

(3) Encourage and support the existence of interdisciplinary and multidisciplinary programs of space research within the university community of the Nation, to engage in integrated activities of training, research and public service, to have cooperative programs with industry, and to be coordinated with the overall program of the National Aeronautics and Space Administration;

(4) Encourage and support the existence of consortia, made up of university and industry members, to advance the exploration and development of space resources in cases in which national objectives can be better fulfilled than through the program of single universities;

(5) Encourage and support Federal funding for graduate fellowships in fields related to space; and

(6) Support activities in colleges and universities generally for the purpose of creating and operating a network of institutional programs that will enhance achievements resulting from efforts under this title.

OBJECTIVES AND STATUS

The Space Grant College and Fellowship Program is composed of three complementary elements. Designated "Space Grant Colleges/Consortia" form the centerpiece. The Space Grant designation recognizes preeminent institutions which are substantially involved in a broad spectrum of NASA research, offer advanced study in aerospace fields, and are significantly involved in related public service. Designation is based on the institution's plan to network with the broader higher education community, establish cooperative relationships with industry and develop innovative public outreach. Designated schools were funded at $150,000-$225,000, conditional upon obtaining matching funds from non-federal sources, and will receive an additional $100,000 for fellowships. In FY 1989, seventeen universities/consortia were selected as Space Grant Colleges/Consortia; in FY 1990, four additional designated schools were selected. The second element, the grant program, enables a broader range of colleges and universities to participate in the Space Grant College and Fellowship Program. Grants will be available to meet unique aerospace challenges or to develop institutional capability. The third element, the Fellowship program, provides a means to meet the critical need for well-trained aerospace engineers and scientists by providing universities selected in the previous two elements funding for undergraduate and graduate fellowships.

CHANGE FROM FY 1990 BUDGET ESTIMATE

The increase of $1,797 thousand is the net result of an additional $3.0 million for the Space Grant College and Fellowship program, offset by a prorata share of $126 thousand for the general reduction as directed by Congress in P.L. 101-144, a reduction of $77 thousand for sequestration, and transfer of $1 million to Educational programs to provide funding for the innovative "classroom of the future" as directed by Congress. The increased funding resulted in the selection of four additional school designated as "Space Grant Colleges/Consortia."

BASIS OF FY 1991 ESTIMATE

In FY 1991 in addition to continued funding for the twenty-one selected Space Grant Colleges/Consortia, NASA plans for the continued phasing in of the grant program element. Specifically, an augmentation of $3 million is requested to bring the total funding level for the Space Grant College and Fellowship Program to $10 million in FY 1991. This augmentation level will permit NASA to broaden the base of universities participating in the civilian aerospace program, a major objective of the legislation, by selecting and funding additional colleges/universities/consortia under the grant program element.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE OPERATIONS

TRACKING AND DATA ADVANCED SYSTEMS

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Advanced systems........................	18,800	19,900	19,345	20,000	RD 18-1
Distribution of Program Amounts by Installation					
Goddard Space Flight Center..............	5,700	6,200	5,600	5,700	
Jet Propulsion Laboratory................	12,865	13,700	13,400	13,960	
Headquarters.............................	235	--	345	340	
Total................................	18,800	19,900	19,345	20,000	

BASIS OF FY 1990 FUNDING REQUIREMENTS

ADVANCED SYSTEMS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Advanced systems........................	18,800	19,900	19,345	20,000

OBJECTIVES AND STATUS

The objective of the Advanced Systems program is to study and develop new higher performance tracking and data handling capabilities which will address planned future mission requirements and will provide improved cost-effectiveness and reliability for overall support of the total mission mix.

This activity is vital to the future of Space Operations programs. Advanced Systems programs focus on assessing and employing technological advances in telecommunications, electronic microcircuitry, and computer sciences. Such effort is essential for the cost-effective application of new technology and for planning future mission support capabilities. Ongoing work includes the investigation of the total data transfer and processing needs of upcoming missions and studies of ground systems and telecommunication links to determine design approaches, and overall tradeoffs for the lowest life cycle costs to support future space missions.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $555 thousand reflects program adjustments to accommodate a prorata share of the general Congressional reduction and a reduction for sequestration.

BASIS OF FY 1991 ESTIMATE

Activities planned for FY 1991 include efforts to obtain location accuracies at the decimeter level for Earth-orbiting spacecraft, which would make possible a new class of high precision Earth observatory missions on the Space Shuttle, Space Station, and free-flying spacecraft. Work will continue on the development of extremely precise radiometric techniques for determining angular direction of future planetary missions to an accuracy of five nano-radians. Such improvements typically lead to improved spacecraft navigation and the conduct of science experiments not previously possible. Studies will continue on ground-based navigation strategies, analyses, and demonstrations for Galileo, Ulysses, and Mars Observer.

Efforts to improve communications between the ground and spacecraft will continue in such areas as the use of millimeter wave frequencies on large diameter antennas; development of more efficient transmitters and highly reliable, low noise telemetry receivers; development of a K-Band terminal for TDRSS-user spacecraft; and, antenna feed systems capable of multiple frequency operation, including millimeter waves. Such improvements in space-to-ground communications can benefit future missions by increasing the amount and quality of the data returned. Optical tracking and communications technology to meet telecommunications needs in the decades ahead will also be investigated both for cost-performance advantages over microwave technology and for potential in space data relay applications.

Future high-rate image data storage and processing requirements for Earth-orbital missions are expected to increase from a current peak use of 85 megabits per second to 300 megabits per second. These requirements result from high-resolution sensors, such as multispectral scanners and synthetic aperture radars, which will be transmitting more data than previous instruments. New techniques and systems will be studied and developed for the storage, processing, and transmission of these high data rates. These studies and developments include new techniques for signal coding and decoding, optical disk buffering and storage, automated distribution and processing of high volume data, improved man-machine interfaces, high-speed modulators/demodulators, and a communications network using an optimal mix of fiber optics, satellites, and local area networks to distribute data to processing centers and users.

Investigations will continue on developing more efficient mission operations control center facilities and providing for the necessary real-time interaction between the ground-based experimenters and their spaceborne experiments. Other investigations are being carried out in the area of expert systems applications, greater use of distributed command terminals, and the performance of orbit and attitude computations onboard the spacecraft.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1991 ESTIMATES

GENERAL STATEMENT

The objective of the National Aeronautics and Space Administration program of space flight, control and data communications is to provide for the operational activities of the Space Transportation System and tracking and communication system support to all NASA flight projects. This objective is achieved through the following elements:

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY: A program to provide a fully capable fleet of Space Shuttle orbiters, main engines, launch site and mission operations control requirements, spares inventory, production tooling, and related supporting activities.

SPACE TRANSPORTATION OPERATIONS: A program to provide the standard operational support services for the Space Shuttle and the expendable launch vehicles. Within Shuttle operations, external tank and solid rocket booster flight hardware is produced; operational spare hardware is provisioned, overhauled and repaired; and manpower, propellants, and other materials are furnished to conduct both flight and ground (launch and landing) operations.

SPACE AND GROUND NETWORK, COMMUNICATIONS AND DATA SYSTEMS: A program to provide vital tracking, telemetry, command, and data acquisition support to meet the requirements of all NASA flight projects using ground-based and satellite (Tracking and Data Relay Satellite System) components.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1991 ESTIMATES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Millions of Dollars)		
Shuttle production and operational capability	1121.6	1305.3	1119.5	1302.0
Space transportation operations	2612.7	2732.2	2636.0	3118.6
Shuttle Unresolved Reduction			-175.0	
Space and ground networks, communication and data systems	717.3	1102.1	975.2	868.8
Total	4451.6	5139.6	4555.7	5289.4

PROPOSED APPROPRIATION LANGUAGE

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

For necessary expenses, not otherwise provided for; in support of space flight, spacecraft control and communications activities of the National Aeronautics and Space Administration, including operations, production, services, minor construction, maintenance, repair, rehabilitation, and modification of real and personal property; tracking and data relay satellite services as authorized by law; purchase, hire, maintenance and operation of other than administrative aircraft; [$4,614,600,000] *$6,499,132,000*, to remain available until September 30, [1991: *Provided*, That of the funds made available under this heading, $1,400,000,000 is for space transportation system only, which amount shall not become available for obligation until April 15, 1990, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided further*, That $75,000,000 of the funds appropriated in section 101(g) of Public Law 99-591 for orbiter production shall be available until September 30, 1991, for all expenses of this account] *1992, of which $1,209,732,000 shall be used only for the purpose of reducing all outstanding debt to the Federal Financing Bank. (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990; additional authorizing legislation to be proposed.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

REIMBURSABLE SUMMARY
(In thousands of dollars)

	Budget Plan		
	FY 1989	FY 1990	FY 1991
Shuttle production and capability development	94,984	88,087	70,858
Space transportation operations	13,981	---	32,900
Expendable launch vehicles	94,337	94,845	90,966
Tracking and data acquisition	28,256	59,900	61,500
Total	231,558	242,832	256,224

NATIONAL AERONAUTICS AND SPACE ADMINSTRATION

FISCAL YEAR 1991 ESTIMATES
DISTRUBTION OF SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Goddard Space Flt Center	Jet Propulsion Lab	Ames Research Center	Langley Research Center	Lewis Research Center	NASA HQ
Space Transportation Sys	1989	3,734,300	1,049,200	824,200	1,713,100	21,300	44,600	2,400	5,600	14,300	10,900	48,700
------------------------	1990	3,755,536	1,101,100	836,100	1,595,200	24,600	72,800	2,800	6,600	9,100	58,400	48,836
Unresolved Reduction	1990	-175,000										
	1991	4,420,600	1,134,600	954,200	2,018,900	24,400	103,000	2,900	6,100	9,700	114,300	52,500
Shuttle Production	1989	1,121,600	366,800	152,500	558,300	19,200	---	2,300	---	400	3,400	18,700
	1990	1,119,500	346,800	118,800	610,000	22,200	---	2,800	---	300	3,500	15,100
	1991	1,302,000	324,000	145,900	786,600	21,900	---	2,900	---	---	4,000	16,700
Space Transporation Ops	1989	2,612,700	682,400	671,700	1,154,800	2,100	44,600	100	5,600	13,900	7,500	30,000
	1990	2,636,036	754,300	717,300	985,200	2,400	72,800	---	6,600	8,800	54,900	33,736
	1991	3,118,600	810,600	808,300	1,232,300	2,500	103,000	---	6,100	9,700	110,300	35,800
Tracking And Data Acqui	1989	717,300	50	---	47,300	---	503,659	122,269	11,100	---	100	32,822
----------------------	1990	975,150	---	---	45,300	---	521,099	137,811	10,400	---	600	259,940
	1991	868,800	---	---	56,800	---	598,562	159,600	15,800	---	100	37,938
TOTAL BUDGET PLAN	1989	4,451,600	1,049,250	824,200	1,760,400	21,300	548,259	124,669	16,700	14,300	11,000	81,522
	1990	4,555,686	1,101,100	836,100	1,640,500	24,600	593,899	140,611	17,000	9,100	59,000	308,776
	1991	5,289,400	1,134,600	954,200	2,075,700	24,400	701,562	162,500	21,900	9,700	114,400	90,438

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT

SPACE TRANSPORTATION SYSTEM

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Shuttle production and operational capability	1,121,600	1,305,300	1,119,500	1,302,000	SF 1-1
Space transportation operations	2,612,700	2,732,200	2,636,036	3,118,600	SF 2-1
Undistributed	--	--	-175,000	--	
Total	3,734,300	4,037,500	3,580,536	4,420,600	

Distribution of Program Amount By Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	1,049,200	1,119,600	1,101,100	1,134,600
Kennedy Space Center	824,200	870,800	836,100	954,200
Marshall Space Flight Center	1,713,100	1,739,000	1,595,200	2,018,900
Stennis Space Center	21,300	18,400	24,600	24,400
Goddard Space Flight Center	44,600	98,000	72,800	103,000
Jet Propulsion Laboratory	2,400	1,800	2,800	2,900
Lewis Research Center	10,900	55,300	58,400	114,300
Langley Research Center	14,300	8,000	9,100	9,700
Ames Research Center	5,600	6,500	6,600	6,100
Headquarters	48,700	120,100	48,836	52,500
Undistributed	--	--	-175,000	--
Total	3,734,300	4,037,500	3,580,536	4,420,600

OFFICE OF SPACE FLIGHT | SPACE TRANSPORTATION SYSTEM

OBJECTIVES AND JUSTIFICATION

The primary program objective of the current activity in the Space Transportation System is to continue the build up in flight rate and maintain the program focus on safety and mission success demonstrated since returning to flight. Space Transportation Systems include development of capabilities and actual operation of the Space Shuttle and Expendable Launch Vehicles in support of a wide variety of national and certain international users. The Space Shuttle is the key element of the Space Transportation System because of its unique capabilities. The Space Shuttle is the first reusable space vehicle and is configured to carry many different types of space apparatus, spacecraft scientific experiments, and national security payloads. In addition to transporting materials, equipment and spacecraft to orbit, the Shuttle offers unique capabilities that cannot be achieved with Expendable Launch Vehicles (ELV): retrieving payloads from orbit for reuse; servicing and repairing satellites in space; transporting humans to and returning them safely from space; operating and returning space laboratories; and performing rescue missions.

Shuttle Production and Operational Capability provides for investment in capabilities to effectively operate the national fleet of Shuttle orbiters. This budget element provides for continued modification and improvement to the flight elements and ground facilities necessary to expand the Shuttle capabilities, increase the flight rate, and expand safety and operating margins. This line item contains the following major subdivisions: Orbiter Operational Capability, Propulsion, and Launch and Mission Support. Orbiter Operational Capability includes orbiter design modifications and system improvements, mission kits, procurement of a spares inventory for the operational orbiter fleet, necessary safety modifications, a structural spares project to maintain the capability to produce and repair orbiter vehicles, and continuation of work started in FY 1988 in support of an Extended Duration Orbiter capability (EDO). The EDO kits are planned to be developed commercially. Propulsion Systems provides for continued development effort to expand safety margins in the Space Shuttle Main Engines and Solid Rocket Boosters as well as investments in production capability necessary to meet the increasing flight rate for the propulsion elements. Also included is the development of an Advanced Solid Rocket Motor (ASRM). Launch and Mission Support provides for Johnson Space Center (JSC) mission operations and support capability development, equipment provisioning of the facilities for launch and landing at the Kennedy Space Center (KSC), and the ground support equipment and associated spares.

Space Transportation Operations provides the standard operational support services for the Space Shuttle and Expendable Launch Vehicles for NASA payload requirements. Within Shuttle Operations, flight hardware is produced, refurbished and repaired; and manpower and propellants,and other materials are furnished to conduct and support both flight and ground operations. The Shuttle Operations program provides for the launch of NASA missions, as well as missions for DOD, other U.S. government agencies and certain commercial and international users on a reimbursable basis. The launch schedule calls for up to nine flights in 1990, ten flights in 1991, ten flights in 1992, and going to maximum of twelve in later years. The Shuttle provides launch services to non-NASA users on a reimbursable basis to satisfy Department of Defense and civil government requirements. A limited number of foreign and commercial launches are planned, based on national security and foreign policy requirements.

The Expendable Launch Vehicle and Services program provides launch services for unmanned civil U. S. government spacecraft that do not require manned presence or the unique capabilities of the Shuttle. Initially, expendable launch vehicle services were procured for a few selected high priority missions previously manifested on the Space Shuttle. The use of these vehicles has expanded as NASA transitions to a mixed fleet capability with the Space Shuttle and ELV's. Consistent with the President's Space Policy and the Competition in Contracting Act, expendable launch vehicle services are acquired from the U.S. private sector whenever possible.

STATUS

The Shuttle Production and Operational Capability budget provides funding in three areas: Orbiter Operational Capability, Propulsion, and Launch and Mission Support. A primary thrust of the current effort in Orbiter Operational Capability is to undertake the design changes, modifications and improvements that are necessary to expand orbiter capabilities, operational characteristics and safety margins. In addition, the logistics program continues to procure a spares inventory and establish a centralized depot repair capability to fully support the flight program. Improvement programs for the orbiter which were initiated prior to the Challenger accident are well on the way to completion. A prime example is the development of an improved auxiliary power unit (APU). The Extended Duration Orbiter (EDO) program which will extend the orbiter on-orbit stay time is being discussed for commercial development and subsequent leasing to NASA. A contract was signed with Rockwell International on August 1, 1987, to produce a replacement orbiter for Challenger using existing structural spares. This orbiter, which was fully funded in FY 1987, is needed to restore the Shuttle fleet to a full operational level. It will be delivered in April 1991. A replacement set of structural spares is being procured under Orbiter Operational Capability.

At KSC, modifications to major facilities and launch site equipment are continuing to provide for more efficient and reliable launch processing. Efforts underway include procurement of the Digital Operational Intercom System (OIS-D), extension of the Launch Equipment Test Facility (LETF) to support testing of the facility modifications, incorporation of fiber optics to improve KSC on-site communications between facilities, and upgrade of the Orbiter Modification and Refurbishment Facility (OMRF) into an Orbiter Processing Facility (OPF) configuration.

At JSC, modifications to on-going activities have been approved to satisfy post-Challenger accident program requirements. Weather prediction and reporting capabilities are being expanded and the capabilities of contingency landing sites are being enhanced. In addition, fidelity and reliability improvements to the training simulators are being given high priority with host computer replacement activity near completion and simulator subsystem replacement continuing.

Development and life certification of the Space Shuttle Main Engine (SSME) is continuing in support of the flight and ground test program. Design modifications on the high pressure pumps and the hot gas manifold are directed at increasing the SSME operating margins, reducing the SSME operating costs, and determining the hardware life and replacement requirements through a certification extension test program. A major near-term effort is to continue to develop design improvements to the high pressure turbopump blades and bearings to enhance the operating margins and extend their operational life. The long range plan is to replace the high pressure turbopumps with redesigned pumps from an alternative source. A contractor was selected in August 1986 for this effort. Redesign of the hot gas manifold is continuing with the design goal of improving flow conditions which will extend engine life by decreasing systems resistance and reducing pump loads. These manifold changes and the alternative source turbopumps will be introduced into the fleet during the early to mid-1990's. The SSME program also includes an advanced technology effort which provides a technology test bed for detailed SSME environment characterization, and will evaluate potential SSME component and system level improvements, as well as evaluate technical advances arising from the Office of Aeronautics and Space Technology's Space Research and Technology program.

In the Solid Rocket Booster projects, evaluation of flight data, including detailed inspection of recovered hardware, will continue. Improvements to the design and production processes will continue in FY 1990 and FY 1991 to enhance product quality and production efficiency. A contractor team has been selected to begin development of an Advanced Solid Rocket Motor (ASRM). The ASRM will enhance reliability and safety with an improved design which does not reply on utilization of existing hardware. Changes in configuration, design details, and materials will be employed to meet more stringent design requirements and enhance safety margins. Production processes will be examined to use the latest applicable technology and automation to enhance reliability and producibility. Significant performance increases are also expected with the ASRM.

The Shuttle Operations budget provides funding in three principal areas: Flight Operations, Flight Hardware, and Launch and Landing Operations. Flight Operations includes training, mission control, flight operations planning, payload and systems analytical integration, mission analysis, flight software, post-flight anomaly resolution, orbiter sustaining engineering and launch support services.

Flight Hardware includes the replenishment of spares inventory, refurbishment and repair of orbiter flight hardware including spares, procurement of external tanks and the interface hardware with the orbiter, refurbishment and manufacturing of solid rocket motors and booster hardware, as well as engineering and logistics support for external tank/solid rocket booster/main engine hardware elements; and maintenance and operation of flight crew equipment. The funding for the external tank and solid rocket motors and boosters includes long lead procurements of raw materials, subassemblies, and subsystems required to sustain production as the flight rate increases.

The Launch and Landing Operations budget provides funding for processing the elements of Shuttle flight hardware as they flow through the ground processing stations at KSC. The Shuttle Processing Contractor (SPC), in conjunction with the Base Operations Contractor (BOC), provides all Shuttle vehicle testing, check-out, servicing, modification and launch processing functions. The Payload Ground Operations Contractor (PGOC) provides processing for all STS payloads from their arrival at KSC through Shuttle integration.

The Expendable Launch Vehicles (ELV) budget provides funding for launch services required for those U.S. civil government scientific and application missions not requiring the unique capability of the Shuttle. These launch services are being acquired from the commercial ELV operators in three performance classes: small, medium and intermediate. Large class missions are being supported by the DOD on Titan IV vehicles, since Titan IV's are not available commercially. The budget provides for acquisition of launch services which includes vehicle hardware, spacecraft integration, mission peculiar modification to the vehicle hardware, launch operations, range support, tracking and data support, NASA technical oversight, and independent verification and validation. Launch services are contracted for missions from both the East and the West coasts.

BASIS OF FY 1991 FUNDING REQUIREMENTS

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Orbiter operational capability	281,800	237,000	218,600	213,600	SF 1-3
Propulsion systems	582,200	727,300	641,600	822,900	SF 1-6
Launch and mission support	257,600	341,000	259,300	265,500	SF 1-9
Total	1,121,600	1,305,300	1,119,500	1,302,000	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	366,800	388,100	346,800	324,000
Kennedy Space Center	152,500	128,800	118,800	145,900
Marshall Space Flight Center	558,300	706,000	610,000	786,600
Stennis Space Center	19,200	16,000	22,200	21,900
Jet Propulsion Laboratory	2,300	1,800	2,800	2,900
Lewis Research Center	3,400	3,500	3,500	4,000
Langley Research Center	400	--	300	--
Headquarters	18,700	61,100	15,100	16,700
Total	1,121,600	1,305,300	1,119,500	1,302,000

OBJECTIVES AND STATUS

The objectives of this program are to provide for the reusable hardware inventory and necessary design modifications and improvements to support the Space Transportation System flight requirements; the development and production of the propulsion systems; and the development of launch site and flight operations capabilities.

With the loss of Challenger in January 1986, the orbiter fleet was reduced to three vehicles. The current orbiter fleet includes Columbia, the orbiter developed and flown on four test and evaluation flights, and two orbiters of a lighter-weight configuration, Discovery and Atlantis. A fourth orbiter (Endeavor) is

now being manufactured and is planned to be delivered in FY 1991. The budget provides funding for necessary improvements, hardware fixes and mission kits for the orbiter fleet to satisfy flight requirements. In addition, the Kennedy Space Center is continuing the procurement of an Orbiter spares inventory needed to support the flight rate buildup. The Extended Duration Orbiter (EDO) development is also included to increase on-orbit stay time in order to improve the Shuttle capability to support payload requirements. The EDO development budget in FY 1990 and FY 1991 is based on financial participation by private industry consistent with efforts to promote more industry investment in space.

Launch and Mission Support provides for Launch Operations and Flight Operations capability to meet STS program objectives. At KSC, the second line of facilities allows simultaneous processing and checkout of orbiters and associated flight hardware from landing through launch. At JSC, mission support provides collateral hardware, principally the extra-vehicular mobility units (EMU), while mission operations capability provides for improvements in the flight support systems. The flight support systems funded by this budget include training and carrier aircraft, additional landing aids and runway end barriers at the primary and contingency landing sites, and replacement/upgrade of equipment in the mission support complex, including the Shuttle mission simulator and the mission control center.

Propulsion systems provide for the production, continued development and extensive testing of the Space Shuttle Main Engines (SSME), the development of the capability to support operational requirements established for the Solid Rocket Booster (SRB), and the development of an Advanced Solid Rocket Motor (ASRM). The SSME program includes: production of main engines necessary for the orbiter fleet and a spares inventory, ground testing in support of engine development, anomaly resolution, product improvement, and advanced development efforts to improve operating margins.

SRB production and capability development activities include static test firing of STS 51-L configuration solid rocket motors for reclamation of reusable hardware and engineering evaluation data; evaluation of returned flight hardware; procurement of manufacturing process control tooling and equipment to support flight rate; and selected studies to continue investigative, analytical, and problem solving activities.

The Advanced Solid Rocket Motor (ASRM) development is targeted for initial flight deliveries beginning in early 1996. The program will include the design, development, test, evaluation, and integration of the ASRM and the design and construction of production equipment for a new government owned, contractor operated production and test facility.

BASIS OF FY 1991 FUNDING REQUIREMENT

ORBITER OPERATIONAL CAPABILITY

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Orbiter	159,000	157,500	125,900	113,400
Extended duration orbiter	20,000	25,000	25,000	15,000
Structural spares	20,300	15,200	25,200	52,400
Systems integration	34,500	9,000	15,400	11,100
Orbiter spares	48,000	30,300	27,100	21,700
Total	281,800	237,000	218,600	213,600

OBJECTIVES AND STATUS

Orbiter production activities includes safety modifications and capability improvements and the development and installation of necessary hardware, software, and procedural modifications to safely fly the orbiters for the foreseeable future. Also, work continues on improvements to: achieve greater operational capabilities, reduce operational costs, and meet system requirements. These improvements include upgrading the general purpose computers (GPC), inertial measurement units (IMU), and auxiliary power units (APU). The brake and the nose wheel steering systems are undergoing modifications to improve landing performance. In addition to these system changes, there are numerous mission and modification kits required for specific flights and payloads. Also included will be the work necessary to continue development of an extended duration orbiter (EDO).

The structural spares program initiated in FY 1983 provided the foundation for the production of a replacement orbiter (OV-105) with a delivery date planned for April 1991. The continuation of this effort is sustaining the capability to produce another vehicle in addition to providing an extra set of structural assemblies. Structural assemblies include the wings, aft thrust structure, engine compartment, crew module (including the nose and cockpit), mid and aft fuselage sections, payload bay doors, vertical tail, and the orbital maneuvering system pods.

The procurement and fabrication of the orbiter spares inventory is ongoing. A concerted effort has been made to better define the spares requirements and production capability at various vendors. A logistics depot has been established nearby KSC for repair and maintenance of orbiter parts. The depot will reduce

logistics program costs and shorten turnaround time. The depot is currently repairing and maintaining minor line replaceable (LRU) and shop replaceable units (SRU) and is developing repair capability for major line replaceable units (LRU). The depot is scheduled to be fully operational in FY 1993.

CHANGES FROM FY 1990 BUDGET ESTIMATE

FY 1990 funding for orbiter operational capability activities decreased by $18.4 million. The orbiter element decreased by $31.6 million. The primary reason for this was a deferral of vehicle modifications. There were no changes in EDO. Structural spares increased by $10.0 million based on recently concluded negotiations for an efficient build. Systems Integration increased by $6.4 million. This increase included development of an infrared Ice Detection capability to be used at the launch site, expanded analysis of Contingency Abort parameters and other systems tasks. Orbiter spares decreased by $3.2 million due to the repricing of initial spares.

BASIS OF FY 1991 ESTIMATE

Orbiter funds provide for the procurement of a logistics capability including an inventory of spares to support operations requirements, the continuation of previously approved systems improvement programs, necessary safety modifications identified as a result of the Challenger accident review process, initiating the manufacture of a replacement set of structural spares, and the engineering analysis and integration capabilities to support the flight rate. Orbiter funding also provides for orbiter support activities such as the remote manipulator system, verification and validation of the avionics system interface and the Convair 990 program of landing system analysis.

The development, qualification and production of flight units for an improved auxiliary power unit (APU) and the upgrade of the general purpose computers (GPC) will continue. The improved APU will have longer life and higher reliability and will require substantially less ground servicing. This configuration will preclude recurrence of problems which have occurred on prior flights such as the formation of wax due to the mixing of lube oil and fuel. The new GPC will add memory and increase operating speed in order to avoid the operational limitations of the current hardware and will result in a more reliable system.

In FY 1991, work on the Extended Duration Orbiter (EDO) will continue with the cryogenic kit being developed under a commercial agreement.

Orbiter funding also covers systems integration of all redevelopment analyses and hardware changes, continued development of the systems integrity assurance program to monitor systems performance and trends as well as procuring orbiter support items.

The orbiter logistics capability program in FY 1991 is continuing the lay-in of LRU's, SRU's, and repair parts to support the flight rate buildup. The funding covers flight hardware spares, ground equipment spares, scheduling, provisioning, documentation, and maintenance training. In addition, funding is included to provide maintenance test equipment and special test equipment for the centralized depot and selected vendor repair sites. The replacement structural spares will also be continued.

BASIS OF FY 1991 FUNDING REQUIREMENT

PROPULSION SYSTEMS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Main engine	403,200	496,600	438,200	430,900
Solid rocket booster	121,000	106,700	75,300	82,900
External tank	7,000	2,700	2,700	--
Advanced solid rocket motor	51,000	121,300	125,400	309,100
Total	582,200	727,300	641,600	822,900

OBJECTIVES AND STATUS

The Propulsion Systems budget provides for the production of the Space Shuttle Main Engines (SSME), the implementation of the capability to support operational requirements and anomaly resolution for the SSME, Solid Rocket Booster (SRB), External Tank (ET) and the development of the Advanced Solid Rocket Motor (ASRM). The SSME program includes the production of the main engines required for the orbiter fleet, the procurement of spare engines, ground testing operations, and development and certification activities to improve operating margins, reliability and durability. The SRB program includes the static test firing of Technical Evaluation Motors (TEM'S) produced prior to the Challenger accident, for reclamation of reusable hardware and for engineering evaluation and data, the replacement of reusable hardware lost during the Challenger accident, as well as completion of SRM tooling modifications and procurement of transportation equipment to support the projected flight rate. Engineering analysis and modifications of booster hardware for certification of a twenty flight use capability will continue in FY 1990 and FY 1991. Three TEM static tests in FY 1991 will be conducted to qualify a new source of rayon used in the manufacture of the solid rocket motor nozzle. The ASRM design and development will be initiated and will employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins.

The SSME program has been structured into three major elements under propulsion system: (1) flight engine; (2) development engine; and (3) advanced development. The total SSME experience now exceeds 2,255 tests, totaling approximately 362,000 seconds of test and flight time. This experience includes 319 tests, exceeding 70,818 seconds of operation, at the full power level (FPL).

The flight engine activity includes the production of new engines, retrofit of improved hardware into the fleet, and anomaly resolution activity.

The development engine activity provides for the hardware, propellants, support for tests, and for the development, certification, and flight certification extension of improved hardware including a redesigned hot gas manifold and near-term high pressure turbopump improvements such as improved blades and bearings. In light of the Challenger accident, the SSME program has delayed all activities associated with the operational use of FPL (109 percent). Single engine testing at these levels has continued to demonstrate margin and safety for the life certification extension test program. In addition, testing is required to demonstrate capability to support extreme abort modes which require operation at FPL.

The advanced development activity includes the alternate turbopump program and the technology test bed. The Rocketdyne high pressure turbopumps are a critical component in the SSME design that have not demonstrated the operational life necessary for cost effective operations. The alternate turbopump program was initiated in 1986 to allow a separate contractor, Pratt and Whitney, the opportunity to design a new pump for greater reliability, safety margin, and longer life. The technology test bed program is conducted with the Office of Aeronautics and Space Technology (OAST) to provide an independent means to evaluate the technical advances arising from the SSME development program, the alternate turbopump effort, and the OAST research and technology program.

The redesign of the SRB to resolve deficiencies in the previous design was completed in FY 1988. Assessment of flight data, including inspection of recovered hardware, will be continuing through FY 1991 and there will be a continuing activity to improve tooling and procedures to enhance process control and product quality. Reclamation of reusable SRM hardware contained in solid rocket motors produced prior to the Challenger accident will also be accomplished through static firing and refurbishment.

FY 1990 saw the closeout of production funding for external tank tooling and equipment to support manufacturing rate capability requirements.

The Advanced Solid Rocket Motor (ASRM) project is intended to enhance the flight safety, reliability and performance of the Space Shuttle fleet. The ASRM will not be subject to the constraint of maximum use of existing hardware that limited changes on the recent SRM redesign activities. The ASRM will employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins. Production processes will use the latest applicable technology and process automation to enhance reproducibility and reliability. The ASRM production facility under construction will be a modern, automated production facility to maximize material and process controls for enhanced reliability. An additional objective of the ASRM is to achieve increased payload capability. The design and development requirements state that there will be no compromise to flight safety and reliability, and

that the impact to other Shuttle elements be held to an absolute minimum. An asbestos-free insulation development program is incorporated into the scope of ASRM development. This requirement is driven by environmental and production safety concerns rather than by technical or performance issues. Costly duplications of qualification tests can be avoided by incorporating this effort into the overall ASRM effort. The ASRM prime contractor will begin phase C/D development activities in the second quarter of FY 1990 with delivery of the first flight hardware scheduled for FY 1996.

CHANGES FROM FY 1990 BUDGET ESTIMATE

FY 1990 funding requirements in Propulsion decreased $85.7 million. The $58.4 million decrease in the main engine program results from a delay in retrofitting the external heat exchanger and delays in major component redesign efforts. Solid rocket booster requirements decreased $31.4 million because the anticipated growth in recertification and recovery tasks was not fully realized. The $4.1 million increase in ASRM is part of the necessary front-end buildup of plant equipment for the planned production facilities. The ASRM facility and equipment requirements will now be funded through direct appropriation rather than the private financing proposed in the FY 1990 budget request. The FY 1990 Construction of Facilities appropriations includes provision for transfer of $35 million to the ASRM program, if required.

BASIS OF FY 1991 ESTIMATE

Funding for the FY 1991 budget supports the development of the ASRM program and the continued development of the production capability of the other propulsion elements (SSME and SRB) based upon meeting requirements of the NASA manifest. The SSME program will continue production of flight hardware and the development programs including necessary improvements to the current configuration and the alternate turbopump. The SRB FY 1991 funding will primarily focus upon continued evaluation and analysis of flight data to thoroughly assess the redesign. Modification of booster hardware necessary to obtain 20 flight use capability will continue as well.

The Request for Proposal (RFP) for the development phase of the ASRM was issued in August 1988. One contractor was selected for development with contract start anticipated during the second quarter of FY 1990. The development program is anticipated to extend for five years with the first flight of ASRM hardware in early FY 1996. The scope of the development will include modification or acquisition of facilities, the development and test of the new design, and production of verification units. The ASRM development is comparable in scope and complexity to that of the SRM, while the technological base is greater than that at the start of the SRM project.

BASIS OF FY 1991 FUNDING REQUIREMENT

LAUNCH AND MISSION SUPPORT

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Launch site equipment....................	104,100	98,500	89,400	114,900
Mission operations and support capability............................	153,500	242,500	169,900	150,600
Total..................................	257,600	341,000	259,300	265,500

OBJECTIVES AND STATUS

This activity supports the development of launch and mission support capabilities, principally at the Johnson Space Center (JSC) and Kennedy Space Center (KSC). The major operational Space Shuttle facilities at KSC includes two orbiter processing facilities, two launch pads, the Vehicle Assembly Building, and three mobile launch platforms. The second launch pad and the third mobile launch platform will be activated during FY 1990. These facilities and the orbiter modification and refurbishment facility (OMRF) support processing and checkout of up to three orbiters in flow. The OMRF will be upgraded to a full up Orbiter Processing Facility in order to accommodate the delivery of the new orbiter in FY 1991 and the increase in flight rate. Funding is also included to develop new supporting capabilities, such as an automated data management system to control the launch processing flow recommended by the Rogers Commission as well as to avoid obsolescence in critical systems such as the launch processing system.

The major mission operations and support capabilities at JSC include the Mission Control Center, the flight and ground support training capabilities, the flight design systems, and development and procurement of crew equipment such as the extravehicular mobility units (space suits). Consistent with the recommendations of the Rogers Commission, improvements are being made in simulation training including new host computers, interface hardware, simulator subsystem replacement, and in the Mission Control Center. Critical improvements in simulation fidelity will be accommodated with the expanded capacity of the new hardware. Reliability required for the longer integrated simulations, and associated maintenance cost, will also be substantially improved with these replacements. Other activities include implementing required modification and upgrades on the T-38 proficiency aircraft and procuring a fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft. Procurement of extravehicular mobility units and

associated improvements are also included. Funding has been included for upgrading landing aids for end of mission and contingency/abort landing sites. Capability improvements have been added for weather prediction and information handling to improve system monitoring, notably for anomaly tracking. Funding for a pre-flight adaptor trainer has also been added to help prepare the crews for a weightless environment.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The Launch and Mission Support total has decreased $81.7 million. The launch site equipment decrease of $9.1 million reflects a deferral of the upgraded central data system element of the Launch Processing System and deferral of OMRF safing and deservicing capability to accommodate the upgrade of the OMRF to an OPF. Mission operations and support capability decreased by $72.6 million. The fourth Shuttle training aircraft estimate was reduced to reflect contract negotiations. JSC equipment being developed and procured to replace existing mission control and equipment was delayed. In addition, other adjustments were made reflecting prioritization of activities to propulsion projects.

BASIS OF FY 1991 ESTIMATE

In FY 1991, Launch Site Equipment includes activities to improve the capability and processing efficiency to support the flight rate requirements at KSC. These include the shuttle processing data management system, a digital internal communications system with associated fiber optics cabling, upgrade of the orbiter modification and refurbishment facility to an orbiter processing facility, replacement equipment for the launch processing system, enhancement of equipment at contingency landing sites and development of a launch team training system (LTTS) for launch crew training and proficiency. Identification, replacement and upgrading of obsolete ground processing and support equipment will be accomplished.

Mission operations and support capability funding in FY 1991 provides for completion of replacement of the host computers and replacement of ADP and other hardware in the Mission Control Center. Continuing projects include development of the Flight Analysis and Design System (FADS), and the "swing" Flight Control Room (FCR), as well as improvements to weather prediction, information handling, mission control systems, and contingency landing sites. Also included is the procurement, development and delivery of a fourth Shuttle Training Aircraft and a second Shuttle Carrier aircraft. In addition, requirements to establish an inventory of crew equipment, principally extravehicular mobility units (EMU), to support the flight rate is included. Finally, STS operations effectiveness work and other support functions are continued to support program-wide requirements including flight safety, mission success, and flight rate capability.

BASIS OF FY 1991 FUNDING REQUIREMENTS

SPACE TRANSPORTATION OPERATIONS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Flight operations	698,400	772,600	758,800	815,600	SF 2-4
Flight hardware	1,313,200	1,236,500	1,205,200	1,467,200	SF 2-7
Launch and landing operations	534,600	553,600	530,200	606,600	SF 2-9
Shuttle operations	2,546,200	2,562,700	2,494,200	2,889,400	
Expendable launch vehicles and services	66,500	169,500	141,836	229,200	SF 2-11
Total	2,612,700	2,732,200	2,636,036	3,118,600	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Johnson Space Center	682,400	731,500	754,300	810,600
Kennedy Space Center	671,700	742,000	717,300	808,300
Marshall Space Flight Center	1,154,800	1,033,000	985,200	1,232,300
Stennis Space Center	2,100	2,400	2,400	2,500
Goddard Space Flight Center	44,600	98,000	72,800	103,000
Jet Propulsion Laboratory	100	--	--	--
Langley Research Center	13,900	8,000	8,800	9,700
Lewis Research Center	7,500	51,800	54,900	110,300
Ames Research Center	5,600	6,500	6,600	6,100
Headquarters	30,000	59,000	33,736	35,800
Total	2,612,700	2,732,200	2,636,036	3,118,600

OBJECTIVES AND STATUS

Space Transportation Operations provides launch services to NASA payloads using a mixed fleet approach of both the Shuttle and Expendable Launch Vehicles (ELV). Launch services are also provided, on a reimbursable basis, to the Department of Defense, other civil agencies, and certain commercial and international users. The Shuttle program launch schedule is based on up to nine flights in 1990, ten in 1991, ten in 1992, to a maximum of twelve in future years. The ELV program launch schedule is based on a mix of launch systems in four performance classes: small, medium, intermediate and large.

The Space Shuttle has demonstrated a broad range of capabilities including deployment of spacecraft and their upper stages, satellite repairs, satellite retrieval, operations using the remote manipulator, integral scientific experimentation using Shuttle and Spacelab systems, extravehicular activity operations, and other operations in which manned intervention holds distinct advantages. These capabilities provide a unique opportunity to enhance the scientific reward of many payloads and the Shuttle will remain the mainstay of NASA's launch capability. The major program elements of Shuttle Operations are Flight Operations, Flight Hardware, and Launch and Landing Operations. These elements provide for the standard service operation of the Shuttle including pre-flight preparation activities, procurement and refurbishment of flight hardware and maintenance and operation of equipment and facilities necessary to support all phases of the Shuttle flight process.

The Flight Operations activity is divided into three major elements: mission support, integration, and support. Mission support includes training, flight operations activities and a wide variety of planning activities ranging from operational concepts and techniques to detailed systems operational procedures and checklists. Integration includes production of flight software, launch support services and sustaining engineering for orbiter systems, cargo analytical integration, and systems integration. The support element includes systems support activity at Johnson Space Center such as aircraft operations, engineering support, and support to the Space Shuttle program office. Shuttle system support for program and integration activities at Headquarters, the Marshall Space Flight Center, and the Stennis Space Center is also included.

The Flight Hardware program element provides for: the procurement of external tanks (ET) and solid rocket booster (SRB) elements including motors, booster hardware, and propellants; replenishment of spare parts inventory and repair of the reusable Space Shuttle Main Engine (SSME); orbiter and crew equipment; ET disconnects; logistics support for the ET, SRB, and SSME flight hardware elements; and maintenance and operations of flight crew equipment. Included in the funding request for tanks and boosters are the long lead time raw materials, subassemblies, subsystems and additional ground testing of the redesigned Solid Rocket Motor (RSRM) necessary to sustain and verify the production of elements in a manner consistent with the flight rate requirements.

Launch and Landing Operations provides for the pre-launch preparation, liquid propellants, launch, and landing operations of the Shuttle and its cargo.

FY 1990 budget authority requirements for Shuttle Operations reflect the impact of the increased FY 1989 availability resulting from the transfer of $227 million in FY 1989 into the Shuttle program. This action was identified in a letter dated December 1, 1989, revising the FY 1989 Operating Plan. The Shuttle provides launch support to approved payloads on a reimbursable basis. There are no planned reimbursements for FY 1990 and planned reimbursable funds for Shuttle Operations for FY 1991 are $32.9 million.

A Mixed Fleet plan was initiated after the Challenger accident as a result of an assessment of NASA's space transportation requirements. This assessment showed that several U.S. Civil Government spacecraft should be launched on Expendable Launch Vehicles (ELV's) in order to provide increased access to space, to assure continuity of space operations, and to enhance mission flexibility. The missions currently planned for launch on ELV's are all spacecraft requiring West Coast launches and selected East Coast launches which do not require the Shuttle's unique capabilities.

BASIS OF FY 1991 FUNDING REQUIREMENT

FLIGHT OPERATIONS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Mission support	230,900	247,500	253,700	280,500
Integration	285,000	300,300	314,100	335,600
Support	182,500	224,800	191,000	199,500
Total	698,400	772,600	758,800	815,600

OBJECTIVES AND STATUS

Flight operations is divided into three major areas of activity: mission support, integration, and support. Mission support includes a wide variety of pre-flight planning, crew training, and operations control activities. The planning activities range from the development of operational concepts and techniques to detailed systems operational procedures and checklists. Tasks include flight planning, preparation of systems and software handbooks, flight rules, detailed crew activity plans and procedures, development and implementation of the Mission Control Center (MCC) and network system requirements for each flight, and operations input to the planning for the selection and operation of Shuttle payloads. Specific flight planning activity encompasses the flight design, flight analysis, and software activities. Flight design products include conceptual flight profiles and operational flight profiles which are issued for each flight as well as support to the crew training simulations and flight techniques. In addition, the flight-dependent data located in the erasable memory (mission-to-mission changes) is developed in the flight design process for incorporation into the orbiter software, Shuttle mission simulator, and MCC systems. Also included are the maintenance and operation of critical mission support facilities including the Mission Control Center, flight simulators, crew training, and flight software reconfiguration and recertification facilities.

Integration includes orbiter sustaining engineering, payload integration into the Shuttle, system integration of the flight hardware elements, orbiter launch support services to the launch site and flight development and verification software. The orbiter sustaining engineering provides all prime contractor engineering activities necessary to requalify the orbiter for flight including FMEA/CIL, design changes and certification reviews. The software activities include the development, formulation, and verification support of the guidance, targeting, and navigation systems software requirements in the Orbiter.

Support includes base operations support to Shuttle operations and systems level support at the manned space flight centers. Base operations support provides for operation and maintenance of aircraft for flight training, crew proficiency and Orbiter ferry requirements; engineering and supporting activities for the orbiter, crew equipment, and flight operations systems; and support to the Space Shuttle program office.

Currently, the resources for Flight Operations are focused upon building to the manifested flight rate, fixing a backlog of system discrepancies and incorporating a large number of changes to ground systems hardware, software, and procedures including those resulting from the ongoing process of analysis and decision-making in the wake of the Challenger accident. Flight preparation, training of ground and flight crews (including system-wide integrated simulations), and other functions are being carried out. These efforts are critical to the safe operation of the Shuttle and significant emphasis is being placed on ensuring that the flight products and crew training satisfy the stringent operational requirements.

CHANGES FROM FY 1990 BUDGET ESTIMATE

FY 1990 funding for the Flight Operations budget decreased $13.8 million. Missions support has increased $6.2 million due to STS operations contract increases, additional support for operations of the Shuttle Avionics Integration Laboratory and also to reflect additional fidelity and verification in the flight design and software reconfiguration activities over previously estimated levels. Integration has increased $13.8 million due to additional manpower requirements, primarily in the orbiter sustaining engineering and systems integration activities. This reflects increased oversight and surveillance by the development contractors to ensure system requirements and specifications are being implemented properly. Support requirements have decreased by $33.8 million primarily because of the increased availability of FY 1989 funds and the allocation of program level flexibility.

BASIS OF FY 1991 ESTIMATE

The Flight Operations portion of the Shuttle Operations budget continues to support activity predominately at JSC to plan for and conduct STS missions from launch to landing. The functions are essentially the same as in the past: to maintain and operate all the ground facilities necessary for flight preparation and execution, and to instruct the flight and ground controller crews; to maintain and operate aircraft for proficiency, training and orbiter ferry requirements; and to perform analyses of and conduct the

mission planning necessary for each mission. The ten missions to be flown in FY 1991 and initial efforts for FY 1992 and FY 1993 will be supported. In addition, because the DOD has initiated a plan to incrementally remove their requirements for secure operations support, some support costs will be incurred in Flight Operations that had previously been funded separately by the DOD.

It also includes the sustaining engineering required to integrate all flight an ground elements and to assure systems safety and integrity; the analytical integration of the payloads into the orbiter and the planning to assure compatibility and certification of interfaces; and support of crew operations and training programs. Orbiter engineering manpower continues the required support of procedure and hardware modifications resulting from the FMEA/CIL reviews, in addition to the sustaining engineering activities that ensure maintainability, reliability, and anomaly resolution during operations.

BASIS OF FY 1991 FUNDING REQUIREMENT

FLIGHT HARDWARE

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
	(Thousands of Dollars)			
Orbiter	314,100	351,800	370,200	397,800
Orbiter spares	(123,600)	(167,600)	(165,900)	(180,000)
Solid rocket booster	704,100	537,000	487,500	691,300
External tank	295,000	347,700	347,500	378,100
Total	1,313,200	1,236,500	1,205,200	1,467,200

OBJECTIVES AND STATUS

The Flight Hardware program element provides for the procurement of External Tanks (ET), the manufacturing and refurbishment of Solid Rocket Booster (SRB) hardware and motors; and operational support to the orbiter including orbiter spares, ET disconnects, spare components and flight support for the Main Engines (SSME) and maintenance and refurbishment of flight crew equipment. Included in the funding request for tanks and boosters are the long lead raw materials, subassemblies, and subsystems necessary to sustain the production of these elements in a manner consistent with the increasing flight rate. Production phasing of these elements is based on the current flight traffic model and is structured to maintain a smooth and efficient buildup of the production capability. SRM Flight Support Motors (FSM's) will begin in FY 1990 with the first static test for qualification of a new source of ammonium perchlorate used in propellant production. FSM's beginning manufacture in FY 1991 will be used to verify production consistency and qualify improved tooling, processes, and design features to enhance process control and product quality. In the ET, production continues at the minimum level of activity necessary to retain manufacturing capability. The Orbiter line element includes Orbiter spares for replenishment of line and shop replaceable units, the manpower for supporting the logistics operation, and the repair capability for flight hardware. SSME includes component and engine overhauls, flight support, and procurement of replacement spare parts. Also included in flight hardware are replaceable spares, field support, and maintenance of crew-related equipment. Some examples of orbiter spare equipment are fuel cells, tiles for thermal protection, tape recorders, leading edge support structures, wheels, brakes and pyrotechnics. The crew-related equipment activities include support to pre-flight training and flight usage of the extravehicular mobility unit, emergency portable oxygen systems, radiation instrumentation, survival radios, closed-circuit television cameras, medical support, and food and other galley-related items.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The orbiter has increased requirements by $18.4 million because of growth in the flight equipment support requirements and a rephasing of SSME spare-component hardware. SRB requirements have decreased by $49.5 million. This decrease reflects the net effect of the increased funding availability in the FY 1989 operating plan, offset by major increases due to extraordinary actions to maintain manufacturing capability for ammonium perchlorate and aerospace grade rayon, as well as increased requirements for SRM manpower and completion of modifications. The external tank has decreased $0.2 million due to a minor rephasing of procurements.

BASIS OF FY 1991 ESTIMATE

Requirements for orbiter flight spares, crew equipment spares, and logistics are based on projected flight rates, maintenance schedules, operational usage, repair times, and lead times to procure or repair flight hardware. The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity for the orbiter, extravehicular maneuvering unit and other crew equipment. The flight equipment processing contract (FEPC) is continuing its buildup to full capability to support the projected flight rates. Main engine hardware provides for manufacturing and delivery of overhauled engines, engine component spares and flight support. Flight hardware requirements activity for the SRB and ET include the procurement of the materials and labor required for refurbishment and fabrication of units which will be flown during FY 1991, as well as the support of the production of units which will be flown thereafter. Additionally, manufacture of flight support motors, for static firing to monitor the consistency of production characteristics and qualify process and design changes, will continue in FY 1991.

BASIS OF FY 1991 FUNDING REQUIREMENT

LAUNCH AND LANDING OPERATIONS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Launch operations	481,600	492,500	471,500	546,400
Payload and launch support	53,000	61,100	58,700	60,200
Total	534,600	553,600	530,200	606,600

OBJECTIVES AND STATUS

Launch and Landing Operations provides for the manpower and materials to process and prepare the Shuttle flight hardware elements for launch as they flow through the processing facilities at KSC. Standard service processing and preparation of payloads as they are integrated into the orbiter are also funded by this category as is procurement of liquid propellants for launch and base support. Support to landing operations at KSC and contingency sites, as required, is also provided.

Operation of the launch and landing facilities and equipment at KSC is the primary function of the Shuttle Processing Contractor (SPC). This includes stacking and mating of the flight hardware elements into a launch vehicle configuration, verification of the launch configuration, and operation of the launch processing system prior to lift-off. Support is also provided by the SPC for booster retrieval operations, configuration control, logistics, transportation, and inventory management.

Support to Shuttle processing is provided by the Base Operations Contractor (BOC). The BOC is responsible for operations support functions such as processing propellants, life support systems, railroad maintenance, pressure vessel certification, Shuttle landing facility and facility and equipment modifications.

Other launch support services included in this budget are maintenance and repair of the central data subsystem, which supports Shuttle processing as an on-line element of the launch processing system; range support provided by the DOD; Shuttle related data management functions such as work control and test procedures; and purchase of equipment, supplies and services not procured under the Shuttle Processing Contractor.

The Payload and Ground Operations Contract (PGOC) is the major contract for the payload processing activities. In Shuttle Operations, the PGOC contractor provides the standard service processing of all STS payloads into an integrated cargo prior to loading into the Shuttle. PGOC will also be the primary contractor for Spacelab and Space Station payload processing at KSC, funded under their respective budgets.

CHANGES FROM FY 1990 BUDGET ESTIMATE

Funding requirements for Launch and Landing Operations reflect a decrease of $23.4 million. This includes a reduction in Payload and Launch Support of $2.4 million for propellants attributable to lower unit cost and a reduction of $21 million in Launch Operations reflecting a savings realized in renegotiating the Launch Support Services contract, and application of the increased FY 1989 availability to offset FY 1990 requirements.

BASIS OF FY 1991 BUDGET

Launch operations funding in FY 1991 provides for manpower and support services necessary for processing launches from KSC. This includes manpower to assemble the SRB's, mate the boosters and tanks, process the orbiter, mate the orbiter to the integrated SRB's and tank, process and checkout integrated flight elements through launch, retrieve the SRB's for refurbishment, and support landing of the orbiter either at KSC or at a contingency landing site when required. Funding also supports the manpower required for sustaining engineering, provisioning, logistics, launch processing system operation and maintenance, and maintenance/modification of all other Shuttle-related ground support equipment and facilities. Flight safety will continue to be emphasized through testing, engineering and quality control.

Payload and launch support funding provides propellants for launch operations and base support, and contractor support for the assembly of individual payloads into a total cargo. This element includes providing launch site support managers to payload customers, verifying cargo-to-orbiter interface, and providing operations maintenance and logistic support to cargo support equipment (such as cargo integration test equipment and multi-mission payload support equipment) and to the payload support areas including the Vertical Processing Facility, Operations and Checkout building, and cargo hazardous servicing facilities. Support required for maintaining the Dryden Flight Research Facility as a contingency landing site is also included.

BASIS OF FY 1991 FUNDING REQUIREMENT

EXPENDABLE LAUNCH VEHICLES AND SERVICES

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Small class	13,900	26,300	12,100	15,000
Medium class	45,000	86,200	76,036	102,900
Intermediate class	6,300	54,900	50,400	101,100
Large class	1,300	2,100	3,300	10,200
Total	66,500	169,500	141,836	229,200

OBJECTIVES AND STATUS

The Expendable Launch Vehicles and Services program (ELV) provides a mixed fleet capability in conjunction with the Space Shuttle to satisfy NASA payload requirements. ELV services are proposed for payloads except when the Shuttle's unique capabilities are required or there is some other compelling circumstance. As part of NASA's launch recovery strategy following the Challenger accident, four scientific spacecraft configured for launch on the Shuttle were transitioned to ELV's. The ELV's for these missions were selected non-competitively. Funding in FY 1990 will continue the procurement of Delta II vehicles and launch services through the DOD under the quid pro quo for the Roentgen Satellite (ROSAT) mission in May 1990 and Extreme Ultraviolet Explorer (EUVE) mission in August 1991. NASA successfully launched the Cosmic Background Explorer (COBE) mission in November 1989 on a Delta vehicle using funds reimbursed by DOD and industry for residual Delta vehicle hardware. Titan III commercial launch service has been procured for the launch of the Mars Observer spacecraft in September 1992. NASA also executed an exchange of residual assets from previous NASA programs for an Atlas/Centaur vehicle for launch of the Combined Release and Radiation Effects Satellite (CRRES) in June 1990.

All subsequent ELV launch services are being acquired by NASA competitively from the private sector, whenever available, to launch civil government payloads in three performance classes: (a) small class capable of launching payloads up to 1,000 lbs. in low Earth orbit, (b) medium class capable of launching payloads up to 10,000 lbs., and (c) intermediate class capable of launching payloads up to 30,000 lbs. Large class mission with payloads up to 40,000 lbs. to low Earth orbit must be acquired through the DOD since no commercial launch services are currently available for this size payload.

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CHANGES FROM FY 1990 BUDGET ESTIMATE

Funding for ELV is reduced a net of $27.7 million based on a delay in initiating the competitive procurement for a series of Small Explorer Satellite class missions. In addition, the Mobile Satellite (MSAT) launch requirement was slipped one year, deferring initiation of funding requirements for this vehicle.

BASIS OF FY 1991 ESTIMATES

Funds are required in FY 1991 to complete procurement through the DOD under the quid pro quo for the launch of the EUVE mission on a Delta II in August 1991. Continued funding will be required to support the procurement of commercial launch services for: (a) a series of projected medium class missions starting with the currently approved GEOTAIL and WIND missions of the Global Geospace Science project targeted for launch in FY 1992 and FY 1993 as well as the Polar, Radarsat, and Mobile Satellite (MSAT) missions targeted for launch in FY 1993 and FY 1994; and (b) a series of Small Explorer Satellite class missions planned to be launched at a rate of two per year beginning in FY 1994. These small class missions are described in a NASA Announcement of Opportunity of the NASA Office of Space Science and Applications dated May 14, 1988. This funding request also takes into consideration the recent NASA/DOD Agreement allocating three of six Scout vehicles currently remaining in the DOD inventory to support one NASA launch in FY 1992 and two launches in FY 1993.

The acquisition of the Titan III commercial launch services will be continued for the Mars Observer mission scheduled for launch in FY 1992. An intermediate class launch service for the Solar and Heliospheric Observatory (SOHO) in 1995 will be continued. The integration of the Comet Rendezvous Asteroid Flyby (CRAF) on a Titan IV vehicle will continue in FY 1991 for a launch in FY 1995. The initial phase of mission integration services for a Titan IV launch of Cassini in FY 1996 will be started.

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1991 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE OPERATIONS

SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS

SUMMARY OF RESOURCES REQUIREMENTS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate	Page Number
		(Thousands of Dollars)			
Space network	256,900	582,300	530,707	331,200	SF 3-4
Ground networks	227,100	269,600	233,576	267,800	SF 3-11
Communications and data systems	233,300	250,200	210,867	269,800	SF 3-20
Total	717,300	1,102,100	975,150	868,800	

Distribution of Program Amount by Installation

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
Marshall Space Flight Center	47,300	49,800	45,300	56,800
Goddard Space Flight Center	503,659	621,000	521,099	598,562
Jet Propulsion Laboratory	122,269	156,600	137,811	159,600
Ames Research Center	11,100	14,000	10,400	15,800
Headquarters	32,822	260,700	259,940	37,938
Johnson Space Center	50	--	--	--
Lewis Research Center	100	--	600	100
Total	717,300	1,102,100	975,150	868,800

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OBJECTIVES AND JUSTIFICATION

The purpose of this program is to provide vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. In addition to NASA flight projects, support is provided on a reimbursable basis for projects of the Department of Defense (DOD), other Government agencies, commercial firms, and other countries and international organizations.

Support is provided for Earth orbital, planetary and solar system exploration spacecraft missions, launch vehicles, research aircraft, sounding rockets and balloons. Included in Earth orbital support are the Space Shuttle, Spacelabs, and scientific and applications missions. The various types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space; (b) acquisition of science and space applications data from on-board experiments and sensors; (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems; (d) reception of television transmissions from space vehicles; (e) transmission of commands from ground facilities to the spacecraft; (f) voice communications with astronauts; (g) transfer of information between the various ground facilities and control centers; and (h) processing of data acquired from the launch vehicles and spacecraft. Such support is essential for operating and maintaining U.S. space assets for achieving the scientific objectives of all flight missions and for executing the critical decisions which must be made to assure the success of these missions.

Tracking and acquisition of data for the space projects is presently accomplished through the use of a worldwide network of NASA ground stations, and by three tracking and data relay satellites in geosynchronous orbit working with a highly specialized ground station. Ground facilities are interconnected by terrestrial and satellite communications circuits linking the spacecraft and their control centers for execution of the missions.

NASA has three basic support capabilities to meet the needs of all classes of NASA flight missions. These are the Spaceflight Tracking and Data Network (STDN), which currently supports Earth orbital missions; the Deep Space Network (DSN), which primarily supports planetary and interplanetary flight missions; and the Space Network, including the Tracking and Data Relay Satellite System (TDRSS), which provides most low Earth orbital mission support.

The STDN, managed by the Goddard Space Flight Center, provided Earth orbital support until the TDRSS became operational. The STDN phasedown was concluded with the closure of several additional ground stations. The DSN, under the management of the Jet Propulsion Laboratory (JPL), provides support to geosynchronous, highly elliptical, and planetary and solar system exploration missions, as well as support to those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Highly specialized computation facilities provide real-time information for mission control and accommodate processing into meaningful form the large amounts of scientific, applications, and engineering data which are collected from flight projects. In addition, instrumentation facilities provide support for sounding rocket and balloon launchings and flight testing of aeronautical research aircraft.

The Space Flight, Control and Data Communications request includes the Space Network, Spaceflight, Tracking, and Data Network (STDN), Deep Space Network (DSN), Aeronautics, Balloon, and Sounding Rocket (AB&SR) facilities, and Communications and Data Systems elements of the program, and provides funding for: (a) TDRSS operations, spacecraft production, and launch support; (b) operations and maintenance of the tracking, data acquisition, mission control, data processing, and communications facilities; (c) the engineering services and procurement of equipment to sustain and modify the various systems to support continuing, new, and changing flight project support requirements; and (d) the spectrum management, frequency allocation, and flight data standards support functions for NASA.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The current estimate for FY 1990 of $975.2 million which is $127 million below the budget estimate, is consistent with Congressional action on the FY 1990 budget. This reduction reflects a general reduction of $100 million, a reduction of $11.4 million for sequestration, and a prorata share of the general reduction directed in P.L. 101-144 of $15.6 million. These reductions will add some risk to the provision of services to the flight programs needing support during the mid to late 1990's.

The FY 1991 budget reflects increasing levels of support activities to flight programs as well as high levels of development and implementation activities for future support capabilities. FY 1991 is characterized by a sharply increased number of spacecraft to be concurrently supported resulting from the flight of a backlog of projects. In 1991, Magellan, Hubble Space Telescope (HST), and the Cosmic Background Explorer (COBE) will be supported throughout the fiscal year, and Ulysses will be added to the deep space mission workload. Concurrent support of additional Spacelab, planetary, and sub-orbital missions will raise the communications, mission operations, and data processing support levels significantly. Ongoing development activities in the Second TDRSS Ground Terminal (STGT) and the Replacement Spacecraft programs will reach the initial stages of integration and test during FY 1991, and the TDRS-5 will be launched. Implementation activities for future missions and support capabilities will also increase with control center and mobile tracking system implementations for the Small Explorers (SMEX) and the initiation of development, late in the fiscal year, for the Customer Data Operations System (CDOS) and Advanced TDRSS which are needed to meet the support requirements of the Space Station era.

BASIS OF FY 1991 FUNDING REQUIREMENT

SPACE NETWORK

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system (TDRSS)	44,800	320,800	280,400	77,200
Space network operations	34,800	39,600	31,507	41,600
Systems engineering and support	31,600	32,400	27,400	34,000
TDRS replacement spacecraft	59,600	44,400	72,000	50,200
Second TDRSS ground terminal/WSGT system replacement	82,100	139,100	117,200	100,000
Advanced TDRSS	4,000	6,000	2,200	28,200
Total	256,900	582,300	530,707	331,200

OBJECTIVES AND STATUS

The Space Network consists of the Tracking and Data Relay Satellite System (TDRSS) and a number of NASA ground elements to provide the necessary services to low Earth orbital spacecraft including the Shuttle. TDRSS is now fully operational with a three satellite constellation, two fully functional and a spare with degraded performance. These satellites are in geostationary orbit with ground facilities located in White Sands, New Mexico. Satellite and ground communication links interconnect the White Sands facilities with the remotely located NASA elements of the network and user facilities.

The FY 1991 request includes funding for: maintenance and operations of the White Sands complex and the NASA elements of the network; support activities such as systems engineering, documentation, and mission planning; equipment modification and replacement; competitive design studies for the next generation of relay satellites; development of additional spacecraft to replace the TDRSS lost with Challenger and to provide network service protection until the next generation of satellites are available; and the implementation of the second ground terminal at White Sands which includes the modernization of the current ground terminal.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system	44,800	320,800	280,400	77,200
(Federal Finance Bank Payment)	--	(227,100)	(227,100)	--

OBJECTIVES AND STATUS

The Tracking and Data Relay Satellite System's (TDRSS) objective is to provide communications services between the user spacecraft and ground facilities. The relay satellites provide space-to-space communications to and from the user spacecraft and relay these communications to the White Sands ground facilities which are interconnected with other network facilities and user control centers. From geostationary orbit, the TDRS provides a nearly six-fold increase in orbital coverage over that possible from ground tracking stations and can accommodate extremely high user data rates ranging up to 300 megabits per second.

TDRS-1 was launched in April 1983, and since that time the network has provided support to Shuttle missions, including Spacelabs and free flying satellite missions such as Solar Maximum Mission (SMM), Earth Radiation Budget Satellite (ERBS), Solar Mesospheric Explorer (SME), Landsat, and Cosmic Ray Background Explorer (COBE). TDRS-2 was lost with Challenger in January 1986.

TDRS-3 and -4 were successfully launched in September 1988 and March 1989, respectively, completing the operational constellation of satellites. TDRS-1 has become the on-orbit spare due to its degraded capabilities. Assembly and test activities continue on TDRS-5 and -6 in preparation for a launch of TDRS-5 in early 1991 to provide a fully functional spare satellite to replace TDRS-1.

Funds earmarked in FY 1989 for repayment of the loans extended by the Federal Finance Bank for TDRS development were reprogrammed to the Space Shuttle Program. The FY 1990 budget includes $227 million for loan repayment. The FY 1991 budget contains no funds for loan repayment as directed by the Administration. The outstanding debt to the Federal Finance Bank will be paid off in FY 1991 based on a inter-appropriation nonexpenditure transfer authorization.

CHANGES FROM FY 1990 BUDGET ESTIMATES

The decrease of $40.4 million reflects program adjustments made to provide a transfer of funds to the TDRS Replacement and to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. This was accomplished by a major crew reduction following the checkout of TDRS-4 on orbit, and the deferral of assembly and test activities planned for TDRS-5 and -6. In addition, the White Sands complex sustaining equipment modifications were eliminated for FY 1990.

BASIS OF FY 1991 ESTIMATE

The primary activity during FY 1991 will be the launch of TDRS-5 to replace TDRS-1 as the on-orbit spare satellite. Assembly and test activities on the sixth spacecraft will follow the launch and checkout of TDRS-5 activities.

NASA will continue payments to Continental Telephone (Contel), the successor in interest and owner/operator of the TDRSS, for service, operations and maintenance of the White Sands Ground Terminal, and for satellite construction and launch support provided during the year.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Space network operations.................	34,800	39,600	31,507	41,600

OBJECTIVES AND STATUS

The objective of Space Network Operations is to provide for the operation and maintenance of the associated NASA ground systems and facilities which, when combined with TDRSS, provide a full array of reliable services to user spacecraft in low Earth orbit. These services are designed to function as part of an integrated operations system and perform specific network functions.

The NASA Ground Terminal (NGT) monitors TDRSS performance, provides fault isolation monitoring for the network, and serves as the communications interface between White Sands and all other facilities. The Network Control Center (NCC) manages and schedules TDRSS services for all user spacecraft, and the Flight Dynamics Facility (FDF) provides orbit determination, trajectory analysis, and position location for selected flight missions supported by the Space and Ground Networks. The overall system has provided services to a variety of missions, and this operational experience provides continuous feedback to the planning, training, staffing, and preparations for upcoming missions to assure that the operational network configuration will be capable of supporting the expanding workload in the early 1990's.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $8.1 million reflects the program adjustments made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. This was accomplished through reductions to funding for vendor supplied troubleshooting expertise and on-call maintenance, software maintenance, and advanced planning and documentation for future flight missions. In addition, some support contract staffing reductions were made. These reductions will add some risk to both reliable network operations and the ability to respond quickly to operational problems.

BASIS OF FY 1991 ESTIMATE

The requested funding provides for operation of network facilities 24 hours per day, seven days per week, and for related hardware and software maintenance. Funding is also provided for a variety of support activities such as operational analysis, mission planning, simulations, user compatibility testing, and documentation.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Systems engineering and support..........	31,600	32,400	27,400	34,000

OBJECTIVES AND STATUS

The objective of Systems Engineering and Support is to provide the engineering services and hardware required to sustain and modify the NASA elements of the Space Network. Engineering services are supplied primarily through support service contracts. These services provide for equipment design and replacement, logistics support, and specialized maintenance and operations support activities including configuration management and procedure development. Ongoing activities include network integration and test, systems reliability analyses, test equipment procurement, and software modifications to sustain network reliability for current users and to prepare to meet the support requirements of new missions such as Hubble Space Telescope (HST), Gamma Ray Observatory (GRO), and Extreme Ultraviolet Explorer (EUVE).

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $5.0 million reflects program adjustments made to accommodate a portion of the general reductions specified by Congress. These reductions entailed the deferral of the NCC central computer replacement, reduced software development, and deferral of the replacement high data rate recorders for the NGT.

BASIS OF FY 1991 ESTIMATE

Funds are requested to provide system engineering, hardware and software maintenance, sustaining engineering support, test equipment, and vendor support to specialized equipment and subsystems within Space Network. Funds are also requested for continued software development and hardware implementation in the NCC to provide the requisite interface to operate with the Second TDRSS Ground Terminal (STGT) currently under development.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
TDRS replacement spacecraft..............	59,600	44,400	72,000	50,200

OBJECTIVES AND STATUS

The objective of the Replacement Spacecraft is to provide a satellite to replace the TDRS-2 lost with the Challenger and to assure Space Network service continuity until the next generation of relay satellites can be developed and deployed. These spacecraft are functionally identical to the current satellites and are fully compatible with the existing system, although some design changes have been made to improve reliability and accommodate parts obsolescence.

Ongoing fabrication activities continue on the F-7 spacecraft following the conclusion of the Critical Design Review (CDR). Deliveries of structural components, reaction control system elements, and electronic components for both spacecraft and communications payload subsystems continue, and the buildup of subsystem components and assemblies will continue through FY 1990.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The increase of $27.6 million reflects the internal realignment of network funding to maintain the Replacement Spacecraft schedule and avoid substantial additional cost increases.

BASIS OF FY 1991 ESTIMATE

The requested funds will continue development activities during the fiscal year. Component level testing will be initiated and spacecraft and payload integration will begin. Manufacturing activities will conclude with the delivery of all spacecraft antennas and the mating of the spacecraft and payload modules. Environmental testing of the spacecraft will begin. Funds are also required to initiate development of the F-8 spacecraft. Based on extensive replenishment modeling using both NASA and DOD computer simulations, this spacecraft is needed to ensure maintenance of network services through the mid-1990's when the first Advanced TDRSS spacecraft becomes available.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Second TDRSS ground terminal (STGT)/ WSGT System Replacement................	82,100	139,100	117,200	100,000

OBJECTIVES AND STATUS

The objective of the STGT is to insure continuity of network service and to minimize the potential loss of critical space assets including science data. The existing ground terminal at White Sands, New Mexico is a single point of failure for the entire Space Network, and a catastrophic failure of this terminal could result in a nearly complete loss of NASA communications and data gathering capabilities for Earth orbital missions.

The replacement of the aging systems in the current ground terminal will necessitate an alternate means of conducting network operations while the replacement activity is underway. The addition of the second ground terminal will provide the means for continuing operational support while the existing terminal is off the air during the modernization. Because the design of the existing ground terminal is limited to the full operations of only two spacecraft, the second terminal will provide the flexibility to operate more spacecraft when mission requirements exceed current capabilities in the mid-1990's.

Replacement of the current ground terminal systems provides a two-fold benefit to long-term network operations. First the aging, error prone, and difficult to maintain architecture of the original terminal will be replaced with updated technology and inherently more reliable architecture of the STGT, simplifying operations and maintenance. Second, the commonality of systems and architecture will allow greatly reduced operational staffing through shared terminal usage of hardware and software maintenance facilities, logistics, and management and engineering support personnel.

The implementation contract was definitized in July 1989 and design/development activities are in progress. The Preliminary Design Reviews (PDR) are completed and the Critical Design Reviews will be completed in late FY 1990. Procurement of off-the-shelf hardware and software is well underway and software design has been initiated. Subcontracts for receivers, demodulators, and antennas have been let and the facility at Bear Creek will be dedicated in early 1990.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $21.9 million was largely due to a three month delay in the definitization of the contract causing a slower build-up of manpower and materials, differences between the executed contract and the government estimate, and increased savings related to the addition of the equipment for the modernization

of the existing terminal to the STGT contract, providing reduced acquisition costs through large lot buys of hardware and avoidance of nonrecurring engineering costs for the modernization. This decrease also accommodates a portion of the general reductions specified by Congress and a reduction for sequestration.

BASIS OF FY 1991 ESTIMATE

The requested funding will provide for the initial fabrication and assembly of the Space-Ground link Terminals (SGLT) and antenna systems during FY 1991. Software and hardware integration will begin and unit testing will be initiated. In addition, non-GE operations contractor personnel will participate in validating man-machine interfaces, systems operability and maintainability through a unique in-plant validation program. Prior to the shipment of systems to White Sands for installation, operations will be simulated, using operations personnel, to insure not only the functioning of hardware and software but also the expertise of the operations staff rather than design/development personnel.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Advanced tracking and data relay satellites (ATDRS).....................	4,000	6,000	2,200	28,200

OBJECTIVES AND STATUS

The objective of the program is to design, develop, and competitively procure technologically advanced relay satellites to sustain Space Network Operations. By the mid-1990's, the stock of ground spare satellites for TDRSS is expected to be exhausted. The ATDRS will provide the capability to extend network service into the 21st century and accommodate the future mission requirements projected for this era.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $3.8 million was due to the delay in initiating the Phase B design studies. The Request for Proposals (RFP) was released in the first quarter of FY 1990, and will lead to the selection of at least three contractors to conduct design studies and prepare design/development proposals late in FY 1990.

BASIS OF FY 1991 ESTIMATE

The requested funding will complete the Phase B design studies initiated in FY 1990 and develop specifications for the detailed design/development phase of the program. A single competing contractor will be selected for the development phase of the program in the fourth quarter of FY 1991.

BASIS OF FY 1991 FUNDING REQUIREMENTS

GROUND NETWORKS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network systems implementation	4,300	4,400	3,700	3,200
Spaceflight tracking and data network operations	64,500	66,600	58,411	55,200
Deep space network systems implementation	39,900	63,400	57,400	60,700
Deep space network operations	95,000	103,500	89,361	108,900
Aeronautics, balloons, and sounding rocket support systems implementation	6,800	11,800	7,700	18,400
Aeronautics, balloons, and sounding rocket support operations	16,600	19,900	17,004	21,400
Total	227,100	269,600	233,576	267,800

OBJECTIVES AND STATUS

The Ground Networks provide support to three broad categories of missions: Earth orbital spaceflight; planetary and solar system exploration; and aeronautics, balloons and sounding rockets. The Deep Space Network, with ground stations located at three sites approximately 120 degrees apart in longitude, provides support to the planetary and solar system exploration missions as well as Earth orbital missions not compatible with TDRSS. Aeronautical, balloon and sounding rocket research is supported by specially instrumented ranges as well as mobile systems. The remaining STDN stations at Merritt Island, Florida, and Dakar provide support to the STS during the launch phase of the mission. Shuttle landing support is provided by a facility at Dryden. Range safety support is provided via Bermuda and Wallops. Some limited non-routine orbital support will also be provided to scientific satellites from the STDN.

Funding for the Ground Networks provides for operation and maintenance of the worldwide tracking facilities, engineering support, and the procurement of hardware and software to sustain and modify network capabilities as required to support new missions. The workload in FY 1991 will include support to

the Space Shuttle and the Ulysses spacecraft launch. Magellan will begin radar mapping of Venus and Galileo will swing by Earth for its second gravity assist during FY 1991. Preparations will be underway for the FY 1992 Mars Observer mission and the Global Geospace Science (GGS) and Collaborative Solar-Terrestrial Research (COSTR) missions.

A new advanced development antenna will be completed at Goldstone in 1990. This antenna will permit research on advanced beam waveguide techniques. These advances will be utilized in the 1991 construction of the 34 meter beam waveguide antenna scheduled to replace an obsolete system at Goldstone and subsequently for systems in Spain and Australia. They will enable the DSN to migrate to higher, more efficient communications frequencies, such as Ka band.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network systems implementation.................	4,300	4,400	3,700	3,200

OBJECTIVES AND STATUS

The Spaceflight Tracking and Data Network (STDN) systems implementation program encompasses the procurement of hardware and attendant engineering services to sustain, modify, and replace existing network capabilities to ensure reliable tracking, command and data acquisition support to NASA's spaceflight missions.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $700 thousand reflects program adjustments that are being made to accommodate a portion of the general reductions specified by Congress.

BASIS OF FY 1991 ESTIMATE

The FY 1991 request includes funds to upgrade equipment and subsystems at the Merritt Island, Florida, and Bermuda STDN tracking stations, which are required along with an operational TDRSS. The request also includes funding for the replacement of obsolete, difficult-to-maintain equipment at these tracking stations and will provide for the procurement of major subsystems spare components, the replacement of older test equipment, and minor equipment modifications to accommodate changes in support requirements.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network operations.....................	64,500	66,600	58,411	55,200

OBJECTIVES AND STATUS

The primary function of the Spaceflight Tracking and Data Network (STDN) system is to provide launch, prelaunch, and landing support to NASA's space missions. In addition, these stations provide limited orbital mission support and serve as backup support resources for orbiting spacecraft including the Space Shuttle in the event that they become unable to be supported by the Space Network. These remaining STDN stations also provide support on a reimbursable basis to spaceflight missions of other United States government agencies (NOAA and DOD), private industry, and other nations.

The STDN now consists of the three ground stations located at Bermuda; Merritt Island, Florida; and Dakar, Senegal. After the Space Network became operational in FY 1989, the stations at Guam; Santiago, Chile; and Kauai, Hawaii, ceased operations. This was accomplished by September 30, 1989. The station at Ascension Island subsequently ceased operations in November 1989.

Each of the three remaining STDN stations has the capability to electronically track spacecraft, send commands for spacecraft and experiment control purposes, and receive engineering and scientific data from the spacecraft. In the case of manned flights, they also have the capability to maintain limited voice communications for crew operations and safety and other project-related purposes.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $8.2 million reflects program adjustments that are being made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding provides for the operation and maintenance of the ground stations remaining after the network phasedown of FY 1989 and FY 1990. This includes the continuing mission support operations at the stations located at Bermuda and Merritt Island, Florida, and operation of the station at Dakar, Senegal.

This funding also provides for the phasedown and closure of the station at Dakar. A portion of this line item provides logistical support to the Deep Space Network, the Space Network Communications and Data Systems, and Aeronautics, Balloon, and Sounding Rocket support operations as well as to the STDN operations.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Deep space network (DSN) systems implementation........................	39,900	63,400	57,400	60,700

OBJECTIVES AND STATUS

The primary role of the Deep Space Network (DSN) is to provide the communication links between planetary and interplanetary spacecraft and the Earth. The DSN receives science and engineering data from the spacecraft and transmits navigation, command and control signals to a variety of spacecraft hundreds to billions of kilometers from Earth.

The systems and facilities required to support spacecraft at the limits of the solar system are highly specialized and include the use of large aperture antennas electronically configured in arrays to receive the extremely weak radio signals. The antennas use ultrasensitive receivers and powerful transmitters. Extremely stable time standards are required for precise navigation of distant spacecraft. Advanced data handling systems are required at both the Network Operations Control Center located at the Jet Propulsion Laboratory (JPL) and the DSN complexes. New systems implementation is required to support the Mars Observer launch, GGS, COSTR, VLBI Space Observatory (VSOP), and Comet Rendezvous Asteroid Flyby/Cassini missions.

The five major objectives of the DSN are as follows: (1) to provide communications links to scientific spacecraft at greater distances than now possible and to increase the capability to receive images at these distances; (2) to increase the frequency range and data rate capability of the ground network to accommodate new deep space mission requirements; (3) to provide mission support for Earth orbiting spacecraft which are non-TDRSS compatible; (4) to provide improved navigation capabilities for precise spacecraft targeting and probe delivery; and (5) to provide emergency support to TDRSS-compatible spacecraft.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $6.0 million reflects program adjustments that are being made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. This reduction will be achieved by deferring the replacement of obsolete equipment.

BASIS OF FY 1991 ESTIMATE

Funding in the FY 1991 request provides for sustaining activities required to keep the DSN functioning in a highly reliable manner. In addition, FY 1991 funding provides for the development of new DSN capabilities to support the following missions and projects: Mars Observer, Topex precision orbit demonstration, Galileo (IO Encounter), VSOP, GGS, COSTR, and CRAF/Cassini. These capabilities include changes to the data systems at the tracking stations and the control center, the stations' radio frequency and receiving systems. The transmitting power levels of the Goldstone and Arecibo radars are being increased to improve the resolution and range for the Solar System Radar program.

Procurement will begin in FY 1991 for the first of three new 34-meter beam waveguide antenna. These three antennas will replace the oldest antennas in the network, which are now at the end of their useful lifespan. The design for the new antennas will be based upon the results obtained from the Advanced Development Antenna at Goldstone, presently under construction.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Deep space network operations............	95,000	103,500	89,361	108,900

OBJECTIVES AND STATUS

The three Deep Space Network (DSN) complex locations--Goldstone, California; Canberra, Australia; and Madrid, Spain--are approximately 120 degrees apart in longitude to permit continuous viewing of planetary spacecraft. Each complex has four antennas -- one 70-meter, two 34-meter, and one 26-meter. The 26-meter antennas are used to support Earth orbiting spacecraft, such as Nimbus-7. The complexes are staffed for round-the-clock operations to support the increasingly heavier workload. Two new planetary spacecraft which require DSN support were launched in 1989 - Magellan and Galileo. In the coming year, Magellan will enter a Venusian orbit and commence mapping that planet. Galileo will flyby Venus in February 1990, receiving a gravity assist on its six-year flight to Jupiter. The DSN will support the European Space Agency's (ESA) attempt to reactivate the Giotto spacecraft, as it nears Earth in early 1990. Final preparations will be conducted for the Ulysses launch, scheduled for October 1990.

A centralized network control center is located at the Jet Propulsion Laboratory (JPL) in Pasadena, California. Other DSN facilities include a spacecraft compatibility test area at JPL and a launch operations and compatibility facility at the STDN Merritt Island tracking station.

The DSN facilities are also used for ground-based measurements in support of experiments in solar system radar and in radio astronomy observations. The network's ultrasensitive antennas are being used in an attempt to learn more about pulsar high energy sources, quasars, and other interstellar and intergalactic phenomena. The solar system radar is useful in understanding surface characteristics of asteroids, comets, moons, and ring systems.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $14.1 million reflects rephasing of network support activities supporting a variety of agency programs to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration which will result in increased operational risk.

BASIS OF FY 1991 ESTIMATES

The DSN operations funding provides for the maintenance and operation of network facilities and the support and engineering effort required for continuing operation of the network. The expected DSN workload in FY 1991 consists of support for Magellan, Galileo (including an Earth gravity assist), and Ulysses, as well as ongoing support to a variety of missions. These missions include Pioneers 10 and 11; Pioneer-Venus; Voyagers 1 and 2; International Cometary Explorer (ICE); Nimbus-7; and Dynamics Explorer (DE). The DSN will also provide emergency and backup support to the TDRSS for Space Shuttle, Hubble Space Telescope, and Cosmic Background Explorer (COBE).

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Aeronautics, balloons and sounding rocket support systems implementation..	6,800	11,800	7,700	18,400

OBJECTIVES AND STATUS

The Aeronautics, Balloon and Sounding Rocket (AB&SR) system implementation program is directed primarily at the systematic replacement of obsolete systems and the upgrade of facilities at the locations discussed below to assure reliable support to NASA's research programs.

The facilities provide the ground support capabilities required to capture the scientific and engineering data from aircraft, balloons, sounding rockets and some Earth-orbiting vehicles engaged in scientific research. The primary fixed facilities are located at the Wallops Flight Facility (WFF), the Moffett Field Flight Complex (MFFC) and the Dryden Flight Research Facility (DFRF).

The WFF, under the management of Goddard Space Flight Center (GSFC), operates a range at Wallops Island, Virginia, which supports aeronautics research as well as sounding rocket and small meteorological balloon launches. In 1986, a capability was established at WFF to provide tracking and data acquisition support to certain highly elliptical Earth-orbiting satellites. WFF also manages the operation of off-site ranges located at the White Sands Missile Range, New Mexico; Poker Flat Research Range, Alaska; and the National Scientific Balloon Facility, at Palestine, Texas. Mobile campaigns for balloon and sounding rocket launches are conducted at various sites, as required, throughout the world.

The ranges at Moffett Field, Crows Landing and the Dryden Flight Research Facility (DFRF) are under the management of Ames Research Center (ARC) and are configured to support aeronautics research. The DFRF has the additional capability to support Shuttle landings.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $4.1 million reflects program adjustments made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. The reduction was partially accomplished by deferring system implementations of aging radar systems at Dryden and S-band systems at WFF.

BASIS OF FY 1991 ESTIMATE

Support to the aeronautical research efforts and scientific experiments using sounding rockets and balloons requires fixed and mobile instrumentation systems which include radar, telemetry, optical, communications, command, data handling and processing systems. To maintain these facilities, replacement parts must be acquired, test and calibration equipment routinely replaced, and equipment refurbished or modified to assure reliable support. Funds are also included for acquisition of new mobile tracking systems to support NASA's small explorer program, the Total Ozone Monitoring Spectrometer (TOMS) mission, and high speed, real time telemetry data acquisition and processing systems to support the agency's expanded role in aeronautics flight research. Also included are funds to operate the receiving ground station of the Alaska Synthetic Aperture Radar (SAR) Facility in Fairbanks, Alaska to track Earth-orbiting SAR satellites.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Aeronautics, balloons, and sounding rocket (AB&SR) support operations......	16,600	19,900	17,004	21,400

OBJECTIVES AND STATUS

The operations element of the AB&SR program includes the operations and maintenance of ground-based instrumentation systems, both fixed and mobile, under the management of the Ames Research Center (ARC) and the Goddard Space Flight Center (GSFC). These facilities support NASA aeronautics, sub-orbital, and a limited number of Earth-orbiting research programs. Funding provides for services and consumable supplies required to operate and maintain the radar, telemetry, data acquisition, data processing, data display, communications and special purpose optical equipment essential to the conduct of these research programs.

The aeronautical test ranges at the Dryden Flight Research Facility (DFRF) and the Moffett Field Flight Complex (MFFC), under the auspices of the Ames Research Center, maintain an active schedule of aeronautics research support. During FY 1989, more than 1500 missions were conducted at DFRF and MFFC. In FY 1990, approximately 1700 aeronautical missions will be supported at these locations. Programs supported by the ranges encompassed a wide variety of activities including revolutionary aircraft configurations, advanced technologies, high performance aircraft, highly integrated control systems and powered lift technologies.

The GSFC activities support aeronautics programs as well as sounding rocket, balloon and Earth orbiting satellite programs at the Wallops Flight Facility (WFF). During 1989, approximately 166 aeronautics missions were supported at the WFF covering such programs as heavy payload mid-air retrieval systems development, XV-15 Aircraft Noise Program, runway friction testing, microwave landing system operations testing, storm hazards research, and the general aviation light aircraft thruster research program. In 1990, approximately 200 aeronautical missions will be supported by WFF.

The sounding rocket program at the WFF conducted approximately 96 launches in FY 1989 of rockets with major scientific payloads. In FY 1990, approximately 100 such launches will be supported. In addition, WFF launched a number of the smaller meteorological and special purpose rockets supporting a variety of research programs. In support of the NASA scientific balloon program, WFF launched 207 large balloons in FY 1989 with major scientific payloads. In FY 1990, approximately 200 large balloon launches will be supported. Earth-orbiting satellites supported include International Ultraviolet Explorer, Interplanetary Monitoring Platform-8, and Nimbus-7, Dynamics Explorer-1, Meteosat, and Landsat.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $2.9 million reflects program adjustments that are being made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration.

BASIS OF FY 1991 ESTIMATE

The funding for AB&SR program operations includes support services contractor operations and maintenance personnel, logistical support, and technical services for the ground-based fixed and mobile instrumentation systems supporting the ongoing sounding rocket, balloon, Earth orbiting satellite and aeronautical research programs. The increased level of support is commensurate with the increased mission workload.

BASIS OF FY 1991 FUNDING REQUIREMENT

COMMUNICATIONS AND DATA SYSTEMS

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Communications systems implementation....	10,400	12,500	11,400	13,500
Communications operations................	109,300	115,500	99,737	120,300
Mission facilities.......................	7,000	7,800	8,300	11,100
Mission operations.......................	30,900	38,700	29,036	40,800
Data processing systems implementation...	26,700	20,900	18,000	22,800
Data processing operations...............	49,000	54,800	44,394	61,300
Total..................................	233,300	250,200	210,867	269,800

OBJECTIVES AND STATUS

Funds requested for the Communications and Data Systems program provide for the implementation and operation of facilities and systems which are required for data transmission, mission control and data processing support. Support requirements have increased sharply with the Shuttle's return to flight, the policy change to divert commercial launch traffic to expendable vehicles, and a waiting inventory of NASA spacecraft which completed development during the launch hiatus. During the current fiscal year, three new spacecraft control and data processing activities being operating for the Cosmic Background Explorer, Hubble Space Telescope, and the Gamma Ray Observatory. This year will also see the acceleration of development activities for new missions which will be launched in the early to mid 1990's.

Communication circuits and services provide for the transmission of data between and among the remote tracking and data acquisition facilities, the TDRSS Ground Terminal, launch areas, and the mission control centers. Real-time information is crucial to determine the condition of the spacecraft and payloads and for the generation of spacecraft and payload control commands. Data received from the various spacecraft must be processed into a usable form for spacecraft monitoring in the control centers and before the transfer of data to the experimenters. Missions supported include Shuttle, Spacelab, NASA scientific and application projects, and international cooperative efforts.

Major activities underway include: completion of the Hubble Space Telescope mission control and data capture system, and mission control and data processing capabilities required to support missions such as Gamma Ray Observatory (GRO), Spacelabs, Upper Atmosphere Research Satellite (UARS), Global Geospace Science (GGS), Collaborative Solar Terrestrial Research (COSTR), Small Explorers (SMEX), and Advanced X-ray Astrophysics Facility (AXAF). In addition, the definition of the Customer Data and Operations System (CDOS) is continuing to develop the system architecture that will provide the nearly 100 times greater data handling and communications capacity needed by Space Station Freedom and the Earth Observing System. Subsequent activities will be to develop an integrated CDOS system design and to prepare for the implementation phase to follow.

	1989	1990		1991
	Actual	Budget Estimate	Current Estimate	Budget Estimate
		(Thousands of Dollars)		
Communications systems implementation.....	10,400	12,500	11,400	13,500

OBJECTIVES AND STATUS

The objective of the Communications Systems Implementation program is to provide the necessary capability in NASA's Global Communications Network (NASCOM) to meet new program support requirements, to increase the efficiency of the network, and to keep NASCOM at a high level of reliability for the transmission of data and commands between U.S. assets in space and respective control centers.

The primary implementation activity is the planning, engineering, and equipment acquisition required to tie together the existing TDRSS ground terminal at White Sands, New Mexico, with the Second TDRSS Ground Terminal (STGT). This requires an integrated communications capability for the control and transfer of data between the two facilities. A second effort under way is the equipment acquisition to replace the Deep Space Network's ground communications data handling capability with higher capacity systems at Madrid, Spain; Goldstone, California; Tidbinbilla, Australia; and the Jet Propulsion Laboratory.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $1.1 million reflects program adjustments that are being made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestraion.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding will provide the sustaining equipment and modifications to support the NASCOM network and provide for the continued engineering and equipment acquisition to support the STGT at White Sands. New equipment will be purchased to replace the obsolete and costly to maintain models presently in use for the message switching system (MSS). Funding will also provide for the increased ground communications data handling capacity required in the Deep Space Network to support the combined data rates of the Magellan, Galileo, and Ulysses satellites. New multiplex/demultiplex equipment will be procured for the GSFC and the JSC to functionally match the equipment installed at the STGT and the upgraded NASA ground terminal at White Sands.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Communications operations................	109,300	115,500	99,737	120,300

OBJECTIVES AND STATUS

NASA's NASCOM interconnects, by means of leased voice, data, and wideband circuits, the tracking and data acquisition facilities which support all flight projects. Also, NASCOM links such facilities as launch areas, test sites, and mission control centers. Goddard Space Flight Center (GSFC) operates the NASCOM and serves as its major switching control point. In the interest of economy, reliability, and full utilization of trunk circuitry, subswitching centers have been established at JPL and Madrid. The NASA flight projects require the transfer of data between the mission control centers and the sites because of the need for real-time control of spacecraft and on-board experiments.

NASA's Program Support Communications Network (PSCN) interconnects the NASA Centers, Headquarters, and major contractor locations through leased voice, data and wideband circuits for the transfer of programmatic and scientific information and provide video teleconferencing capability and other administrative telecommunications services. Marshall Space Flight Center (MSFC) operates the PSCN and serves as its major switching control point.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $15.8 million reflects program adjustments that are being made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. The adjustments include delaying implementation of new requirements on the PSCN and NASCOM. New requirements on NASCOM will be met by time-sharing existing circuitry at the expense of operational performance.

BASIS OF FY 1991 ESTIMATE

The FY 1991 funding for the communications operations program provides, support for the increasing number of missions being currently supported, the circuits and services required to operate and maintain the Network. International communications satellites and cables will continue to provide digital wideband services to all the overseas tracking stations. Domestic satellite systems and terrestrial networks will continue to service the continental United States stations. The planned funding for increased bandwidth required for the Spacelab-type missions and simultaneous support for the deep space projects with wideband data links to Spain and Australia has been deferred. The increasing Shuttle mission load will no longer allow for cost savings by reducing and delaying communications services.

The Program Support Communications Network (PSCN) provides for the circuits and facilities for programmatic operations such as data transmission and computer-to-computer data sharing for NASA Centers and Headquarters. In FY 1991, funds are required to operate and maintain the PSCN hardware and wideband satellite and terrestrial circuits at all NASA locations and selected contractor sites. The network will support all NASA programs and projects such as the Shuttle, Hubble Space Telescope, and Space Station Freedom.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Mission facilities......................	7,000	7,800	8,300	11,100

OBJECTIVES AND STATUS

The Mission Facilities implementation program provides the capabilities needed for the command and control of NASA's unmanned scientific and applications satellite programs. Command and control of the spacecraft and on-board experiments are carried out via the Payload Operations Control Centers (POCC's) and related mission support systems.

The POCC's are responsible for the receipt, processing, and display of spacecraft engineering data and the generation of commands. Four POCC's currently monitor and control numerous spacecraft. In addition, a new dedicated control center is nearing completion for control of the Hubble Space Telescope scheduled for launch in mid FY 1990. Related mission support systems include a Johnson Space Center/Goddard Space Flight Center Shuttle POCC Interface Facility (SPIF) and a Mission Planning/Command Management System to schedule spacecraft support and generate command sequences for transmission to the spacecraft by the POCC's.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The net increase of $0.5 million reflects the start of the development of an integrated mission control capability for the Small Explorer (SMEX) missions, after an adjustment to accommodate a portion of the general reductions specified by Congress. This new series of low cost spacecraft will require a new and lower cost approach to supporting mission operations.

BASIS OF 1991 ESTIMATE

The FY 1991 budget request includes funds for continued implementation of mission control capabilities at GSFC for the Small Explorer (SMEX) missions and at MSFC for the Advanced X-ray Astrophysics Facility (AXAF). Also in FY 1991, funds are included for mission unique modifications to the existing Multi-satellite Operations Control Center (MSOCC) at GSFC for control of the Upper Atmosphere Research Satellite (UARS), Extreme Ultra-Violet Explorer (EUVE), GGS, COSTR, and various Shuttle attached payloads.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Mission operations......................	30,900	38,700	29,036	40,800

OBJECTIVES AND STATUS

The Mission Operations program in FY 1990 provides for the operation of the mission control centers and the related software and support services necessary for the monitoring and control of in-orbit spacecraft and prelaunch preparations for new spacecraft.

Control facilities for spacecraft/payload operations have the capability for receiving, processing, and displaying spacecraft engineering and telemetry data and for generating commands in response to emergencies determined by the spacecraft analysts and preplanned command sequences generated in advance to carry out the mission objectives. Each facility is operated 24 hours per day, 7 days per week in mission support. For Shuttle missions with attached payloads operated by GSFC, there is a specialized GSFC Shuttle Payload Interface Facility (SPIF) which processes and provides for the display of Shuttle-unique data that is necessary for payload control.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $9.7 million largely reflects program adjustments made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. The reductions will result in a slow down of the unique software development for EUVE, GGS, COSTR, and the deferral of the build up of institutional capabilities to support the workload resulting from the flight manifest.

BASIS OF FY 1991 ESTIMATE

The FY 1991 budget request includes funds to operate the control centers and supporting facilities for control of on-orbit missions including the recently launched COBE and to develop control center software to support upcoming missions. In mid FY 1990, the Hubble Space Telescope (HST) will be launched, followed by the Gamma Ray Observatory (GRO) later in 1990. The funds will provide the first full year of round-the-clock, seven days per week, operation of HST and GRO to monitor and control the observatories to obtain scientific data. The funds will also provide software to enhance the institutional capabilities for recording control center information, handling higher spacecraft data rates, and interfacing to the JSC Shuttle control center. These enhancements are required due to the increases in the number of spacecraft to be controlled by the institutional facilities and the higher data rates and sophistication of the new spacecraft. Also, unique software development will continue for the UARS mission, and the unique software development activities will increase for the EUVE, GGS, and COSTR spacecraft to meet the planned launch dates. Finally software development will begin in anticipation of the next generation of HST instruments scheduled to replace the current instruments.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Data processing systems implementation...	26,700	20,900	18,000	22,800

OBJECTIVES AND STATUS

The Data Processing Systems Implementation program provides for the procurement of equipment and related services for the large data processing and computation systems at the Goddard Space Flight Center (GSFC). These systems support both the operational and payload requirements of flight missions. To meet operational requirements, these systems determine spacecraft attitude and orbit and generate on-board commands to the spacecraft subsystems. In support of spacecraft payloads, the systems process the data from science and applications experiments for subsequent transfer to the experimenters for analysis.

Major computation capabilities include the Flight Dynamics Facility which performs the real-time attitude, orbit computation and flight maneuver control functions and the Mission Operations and Data Systems Information Network (MODSIN). Also included is the improvement in the test bed facility to be used for prototyping, testing, and evaluating maturing technologies resulting from the Advanced Systems Program. Promising technologies for application to future support will be investigated in the areas of remote payload operation and control, expert systems, high speed data processing, high level languages, and very large scale integration (VLSI). In addition, there are four major systems for processing payload data: 1) the Telemetry On-Line Processing System (TELOPS) which routinely supports a number of Earth-orbiting spacecraft; 2) the Image Processing Facility (IPF) which can support satellite imaging requirements; 3) the Spacelab Data Processing Facility (SLDPF) which has provided support to the Spacelab missions and the Shuttle Imaging Radar-B experiment; and 4) the Hubble Space Telescope Data Capture Facility (HSTDCF) which will capture, process, and forward to the Science Institute Facility the packetized telemetry data from the Hubble Space Telescope spacecraft. Significant activities in this program continue at GSFC to keep the large systems viable and responsive to project support requirements. Implementation continues on new systems to process data from the Gamma Ray Observatory (GRO) and the Upper Atmosphere Research Satellite (UARS) missions.

Two contractors have been chosen for definition studies and preliminary design for the Customer Data and Operations Systems (CDOS) in FY 1989. These studies will be for new institutional communications and data systems capabilities required to support the Space Station Freedom and other payloads in the Space Station era and are scheduled for completion in FY 1990.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $2.9 million reflects program adjustments made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. The reductions are in the Mission Operations Data Systems Information Network (MODSIN) and deferral of the generalized attitude application software and data processing development.

BASIS OF FY 1991 ESTIMATE

The FY 1991 budget request will provide continued funding for improvements in the existing computation at GSFC which provide real-time support to NASA spacecraft. The budget request also includes funds to complete the upgrade of the existing TELOPS system in order to develop a generic time division multiplexed (TDM) system for processing data. The Upper Atmosphere Research Satellite (UARS), will be the first user. The handling of UARS data will serve as a demonstration for providing such support to other users and allow trade-off analyses between development costs and support risks for future missions. Funds are also requested for upgrading the data processing capabilities at GSFC to facilitate the exchange of data within the data processing complex and with other mission support facilities.

Requested funding provides for the procurement and maintenance of an adequate supply of unique spare parts to replace failure-prone and high-maintenance electronic modules, to provide test equipment, and to undertake minor modifications and hardware fabrication associated with new equipment installation and reconfiguration.

Funds are included in the request for continuing the evaluation of Earth Observing System and Space Station Freedom support requirements and the capabilities needed to meet those requirements. The systems definition study will be completed for the Customer Data and Operations Systems (CDOS) which will provide a preliminary design and specifications leading to a projected system readiness date of September 1994.

	1989 Actual	1990 Budget Estimate	1990 Current Estimate	1991 Budget Estimate
		(Thousands of Dollars)		
Data processing operations...............	49,000	54,800	44,394	61,300

OBJECTIVES AND STATUS

Information received in the form of tracking and telemetry data from the various spacecraft must be processed into a usable form before transfer to the experimenters. This transformation and computation process is performed as part of the data processing function and applies to a wide variety of programs, ranging from the small explorer satellites to more complex imaging satellites.

In addition to the actual processing of data, upcoming projects require extensive prelaunch orbit analysis. Spacecraft position and attitude predictions analyses are also required to develop operational sequences and procedures. Benefits from these studies include optimization of systems resources such as, look angles for maximum science data return during the actual spacecraft operation. All these analyses result in the generation of flight dynamics requirements and lead to the development of attitude and simulation support systems.

Telemetry data is the primary product of spacecraft, and it is through reduction and analysis of this data by the experimenters that the mission objectives are achieved. Data are processed to separate the information obtained from various scientific experiments aboard the spacecraft, to consolidate information for each experimenter, to determine spacecraft attitude, and to correlate these measurements with time and spacecraft position data. Four facilities, the Image Processing Facility (IPF), the Telemetry On-Line Processing System (TELOPS) facility, the Spacelab Data Processing Facility (SLDPF), and the Hubble Space Telescope Data Capture Facility (HSTDCF) have been established at the Goddard Space Flight Center to preprocess different types of raw experiment data. Sustained operations of these facilities is needed to support the ongoing spacecraft in-orbit.

The IPF, initially established to handle image data from the Landsat-1 satellite, has supported many missions over the ensuing years. The TELOPS handles satellite non-image data which is received in a digital form from the tracking stations via NASCOM. It is capable of electronically storing large volumes of telemetry data, thus eliminating most of the tape and tape handling operations. Facility management, maintenance and operations, and software development support for the image and non-image data processing facilities are also provided. The operation of the SLDPF is included along with software development and maintenance required for attitude determination, flight maneuvers, mission simulations for upcoming flight programs; and the Mission Operations and Data Systems Information Network (MODSIN) applications and data base development.

CHANGES FROM FY 1990 BUDGET ESTIMATE

The decrease of $10.4 million reflects program adjustments to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. This budget reduction will result in the delayed delivery of data from some of the missions supported. In addition, reductions were made in data systems prototyping, operations and maintenance of computer operations and attitude support activities.

BASIS OF FY 1991 ESTIMATE

The FY 1991 budget request provides for operation of the various computation and data processing facilities including the SLDPF which provides unique hardware and software support to Spacelab and Dedicated Discipline Laboratory (DDL) missions. Pre-mission, mission and post-mission support for FY 1991 launch of STP, IML-1, TSS, ASP, Starlab, Atlas-1, and SL-J missions is required. In addition, preparation for future missions such as USML-1, SL-D2, Atlas-2, and Astro-2, will be continued. Support for ongoing spacecraft, such as, IUE, ICE, ERBS, DE, and COBE consists of software enhancements and maintenance on a continuing basis in order to perform flight control and maneuver operations and for the data processing activities. Funding is required to support the Space Station Platform Flight Dynamics analysis and CDOS software support environment (SSE) buildup.

Application software development, prototyping, and system testing are continuing for upcoming science and applications missions such as AXAF, GGS, COSTR, GRO, UARS, and EUVE. Funding is also required for the Solar Heliospheric Observatory (SOHO) element of COSTR.

END

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